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STRATIGRAPHY, STRUCTURE, SEDIMENTOLOGY, AND NATURAL GAS POTENTIAL OF THE LOWER CRETACEOUS MANNVILLE GROUP IN THE LEISMER AREA, NORTHEASTERN ALBERTA.

BY

©

JAMES H.T. RIDDELL

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

DEPARTMENT OF GEOLOGY

Edmonton, Alberta
SPRING 1993

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S. George Pemberton

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C N Stelck

J. O. Scott

Date April 22, 1993

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Abstract

Some 1300 square miles and 450 well cores and geophysical logs have been studied, outlining current reserves of natural gas and possible further accumulations of same from the Lower Cretaceous Clearwater Formation and McMurray Formation of the Mannville Group. The McMurray Formation consists of an interpreted progression of fluvial to marginal marine deposits representing transgression of the Bullhead sea within a well defined paleovalley. The most significant natural gas reserves are found in Upper McMurray deposits where distributary channels feeding northwestern prograding shorelines have completely eroded the muds of the Middle McMurray, leaving continuous reservoir throughout the McMurray Formation. The Clearwater Formation is interpreted as northward prograding nearshore bars trapping natural gas stratigraphically to the north, and structurally to the east, primarily by the North-South trending salt collapse structure originating within the Elk Point Group. 18 maps and 9 cross-sections detail the stratigraphy, structure, and natural gas potential in the study area.

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Introduction

The Lower Cretaceous Mannville Group in Northeastern Alberta contains an estimated 909 billion barrels of bitumen (See Table 1;Keith *et al.*, 1987.), mostly uneconomical to produce with conventional methods. It is the relatively high price of enhanced oil recovery methods currently in practice that has inhibited exploitation. The major portion of this bitumen is found in the McMurray Formation, a highly complex unit which unconformably overlies Devonian strata. The main objective of this thesis is related to evaluating the natural gas which coexists with heavy oil in the McMurray Formation, the Wabiskaw Member of the cclearwater Formation, and also in selected horizons stratigraphically higher within the Clearwater Formation. The study area comprises 1300 square miles and was evaluated by using both core and geophysical logs for over 450 wells in the area which average 400 m total depth.

The depositional history of the Clearwater Formation including the Wabiskaw Member, appears to be relatively simple to reconstruct, however, the McMurray Formation has proven highly complex. Previous authors have interpreted the McMurray Formation as fluvial, deltaic, estuarine, and shallow marine depositional

Area	Deposit	Areal Extent 10^3 ha	Mean Pay m	Bitumen in place $10^9 m^3$	Bitumen in place 10^9 bbls
Athabasca	McMurray/Wabiskaw	4,680	34	144	909
	Grand Rapids	689	7	7	43
	Grosmont/Nisku	4,666	10	61	383
				212	1,335
Cold Lake	Grand Rapids	1,603	7	20	123
	Clearwater	561	12	11	67
	McMurray/Wabiskaw	666	5	4	25
				35	215
Peace River	Bullhead/Gething	987	9	12	75
	Debolt/Shunda	228	20	7	47
				19	122

Table 1. Bitumen Reserves of Alberta's Oil Sands
(modified after Alberta Energy Resources Conservation Board, 1985)

units.(Stewart,1963; Flach,1984; Mossop, 1980; Carrigy,1971; Pemberton *et al*, 1982; Ranger and Pemberton,1988; Rennie,1987). This thesis provides an original interpretation within the study area combining some of the previously developed ideas into an original, more refined reconstruction of the McMurray Formation. Major emphasis has been placed upon interpreting the uppermost McMurray Formation as it holds the immediate economic importance.

Major geologic features in the study area include structure caused by salt collapse within the underlying Elk Point Group, subsidence of the Peace River Arch, erosion of the Paleozoic unconformity, and the characteristic southwesterly dip of the Western Canadian Sedimentary Basin.

Combining this structure with the depositional model provides a strong predictive tool for mapping and developing natural gas reserves. This thesis will document the generation and evaluation of potential plays within the actively explored area; the immediate result being an exploration and development strategy for the two most attractive prospects.

Study Area

The Athabasca oil sands have an areal extent of 4.68 million hectares and a bitumen content of over 909 billion barrels, by far the largest single accumulation of hydrocarbons in Alberta and possiby the world. (see Table 1). An active natural gas exploration area within the boundaries of the deposit is the focus of this thesis. The study area encompasses townships 76 through 79 and ranges 3 through 11 West of the fourth meridian, (Figure 1.); within which are the Leismer, Chard, Hardy and Graham natural gas fields. The data availiable are sufficient for the purposes of this study and, because it is an active exploration area, will continue to rapidly expand. The first substantial interest in the area occurred in the late 1960's and after a ten year lapse, has steadily increased. In 1989 alone, over 45 wells were drilled; one can see how quickly the database is growing and consequently, how our understanding of the geology is evolving. The database includes all wells drilled in the area before the 1989-90 winter drilling season. Wells drilled after that, due to the one year confidentiality privelidge extended to the operators of the wells, were unavailiable for inspection. The study makes use of information gained from approximately 475 wells, of which over 90% were drilled after 1975. The

Location Map

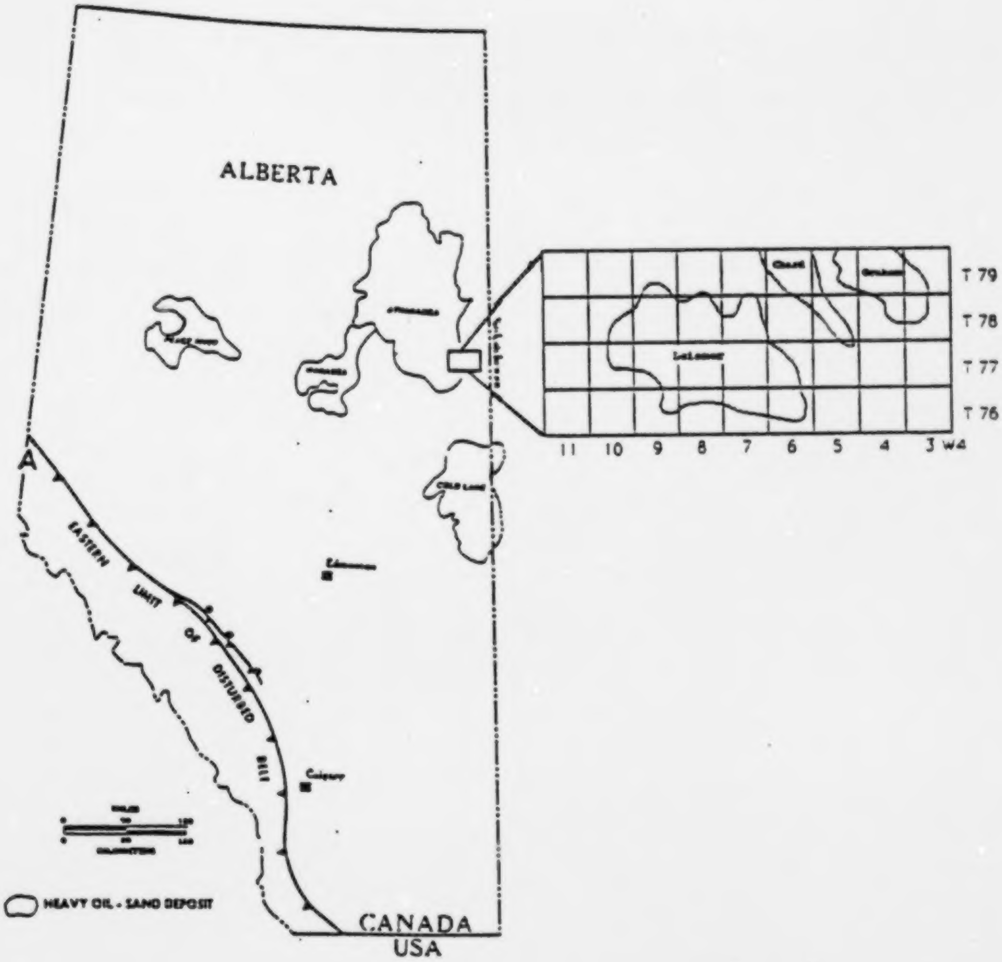

ALBERTA
A
EASTERN LIMIT OF DISTURBED BELT
HEAVY OIL - SAND DEPOSIT
CANADA
USA
T 79
T 78
T 77
T 76
11
10
9
8
7
6
5
4
3 W4

Figure 1. Map of Alberta showing major Cretaceous oil sands deposits. Inset - study area showing major gas accumulations. (modified after Moshier and Waples, 1985)

few wells drilled in the late 1960's provide only spontaneous potential and resistivity logs. Post 1975 wells, however have a comprehensive complement of logs including the spontaneous potential, resistivity, and compensated neutron formation density logs. In addition to this extensive geophysical database, 105 wells have been cored within the Mannville Group from which a representative suite have been examined. Seimic and outcrop observations were also incorporated but to a limited extent.

Stratigraphy

Within the study area the Mannville Group consists of the lowermost McMurray Formation which is directly overlain by the the Clearwater Formation and its' lowermost Wabiskaw Member. This in turn is overlain by the Grand Rapids Formation. The Mannville group is bounded unconformably above by the Joli Fou Formation and below by the angular Sub-Cretaceous unconformity (Figure 2). The deposition of the Manville Group is in response to transgression of the Boreal sea over the erosional unconformity of the underlying Devonian strata. The Athabasca Channel formed in response to the salt solution and subsequent collapse in the underlying

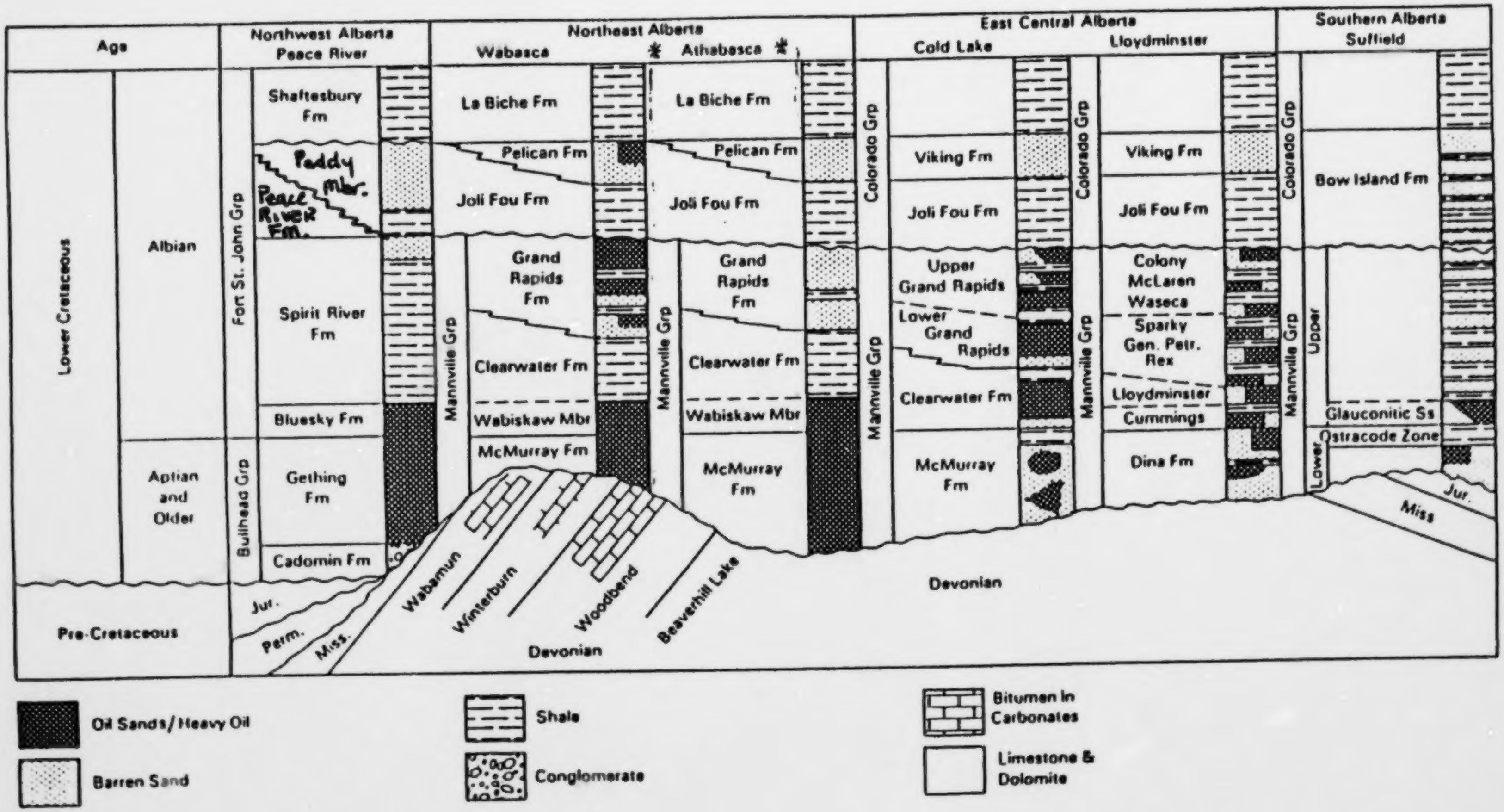

Age
Northwest Alberta
Peace River
Northeast Alberta
Wabasca
*
Athabasca
*
East Central Alberta
Cold Lake
Lloydminster
Southern Alberta
Suffield
Lower Cretaceous
Albian
Aptian and Older
Pre-Cretaceous
Fort St. John Grp
Bullhead Grp
Shaftesbury Fm
Paddy Mbr.
Peace River Fm.
Spirit River Fm
Bluesky Fm
Gething Fm
Cadomin Fm
Mannville Grp
La Biche Fm
Pelican Fm
Joli Fou Fm
Grand Rapids Fm
Clearwater Fm
Wabiskaw Mbr
McMurray Fm
Colorado Grp
Viking Fm
Upper Grand Rapids
Lower Grand Rapids
Colony
McLaren
Waseca
Sparky
Gen. Petr.
Rex
Lloydminster
Cummings
Dina Fm
Bow Island Fm
Upper
Lower
Glauconitic Ss
Ostracode Zone
Jur.
Perm.
Miss.
Wabamun
Winterburn
Woodbend
Beaverhill Lake
Devonian
Miss
Oil Sands/Heavy Oil
Barren Sand
Shale
Conglomerate
Bitumen in Carbonates
Limestone & Dolomite

Figure 2. Regional stratigraphy of the Lower Cretaceous of Alberta. (modified after Keith et al, 1987)

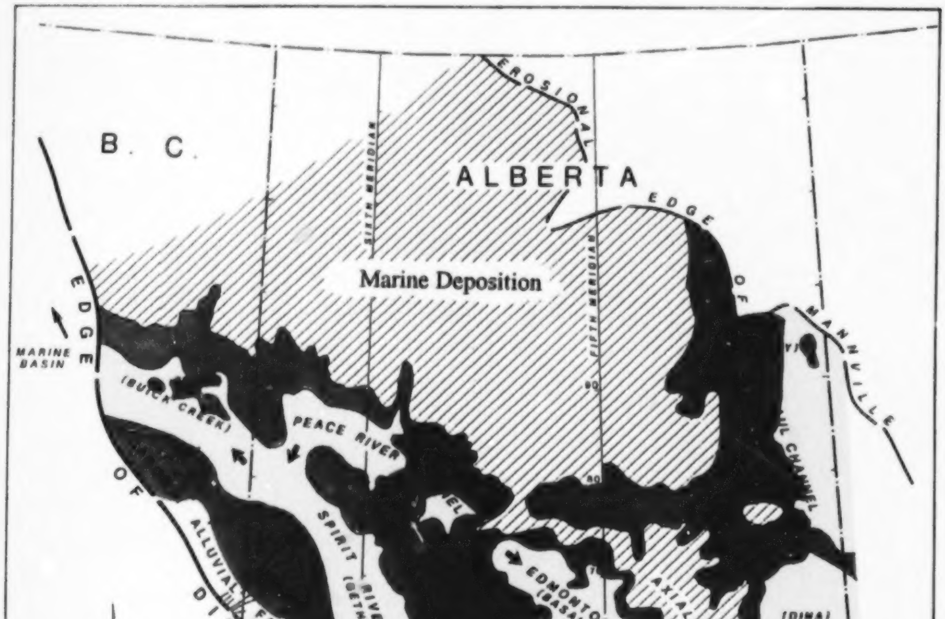

B. C.
ALBERTA
EROSIONAL EDGE OF MANNVILLE
Marine Deposition
SIXTH MERIDIAN
FIFTH MERIDIAN
EDGE OF DISTURBED BELT
MARINE BASIN
(BUICK CREEK)
PEACE RIVER CHANNEL
SPIRIT RIVER CHANNEL (GETHING)
ALLUVIAL FANS
EDMONTON CHANNEL (BASAL QUARTZ)
AXIAL HIGH
(DINA)
PEMBINA HIGH
EDMONTON
BELLSHILL LAKE CHANNEL
(CUTBANK)
LOWER MANNVILLE FLUVIAL SYSTEMS
Major fluvial system
Continental area
High areas (thin to non-deposition)
Gas field
Oil field
0 50 100 Miles
0 100 200 Kilometres

Figure 3. Paleogeography of the Lower Mannville fluvial systems; The first phase of Mannville Group deposition. (modified after Master's , 1985)

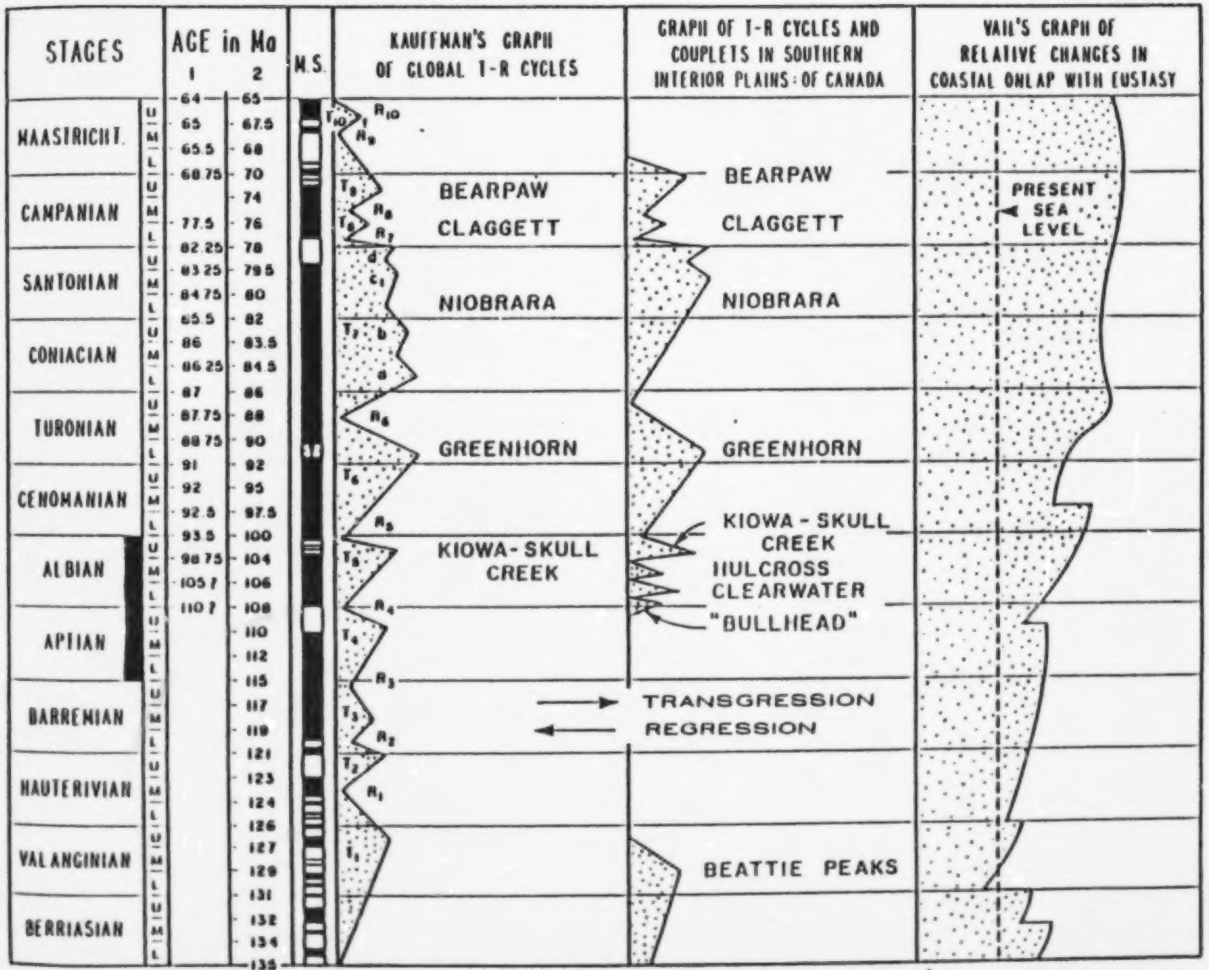


Figure 4. Global and Western Canadian Sedimentary Basin Transgressive - Regressive Cycles. (modified after Caldwell, 1984)

Elk Point Group which will be discussed in greater detail later. The Athabasca channel is bounded by Devonian highlands to the west and south, and Precambrain basement to the east. The evolution of the basement has reversed the predominant southward drainage of the area south of township 92 to join drainage patterns that were draining to the northwest into the Cretaceous Interior Seaway (Flach and Mossop, 1985). This Early Cretaceous high is thought to be an extension of the Peace River Arch which reacted to Neocomian uplift of the Precambrian shield to the northeast (Christopher, 1980). These fluvial systems incised the Pre-Cretaceous unconformity surface creating a high relief area of up to 120 m (Flach, 1984; Figure 3). Lowermost McMurray Formation deposits are correlative with more southeasterly Dina Formation deposits near Lloydminster (Christopher, 1980). During Albian time, a major rise in sea level created the Cretaceous interior seaway, also referred to as the Bullhead Sea (Figure 4), which corresponds to the deposition of the McMurray Formation. It is this resulting interaction between the northeasterly draining fluvial system and the southwestern transgression of the Bullhead sea that provided the unique characteristics of the resulting middle McMurray Formation estuarine deposition (Figure 5). The Upper McMurray Formation was deposited as the

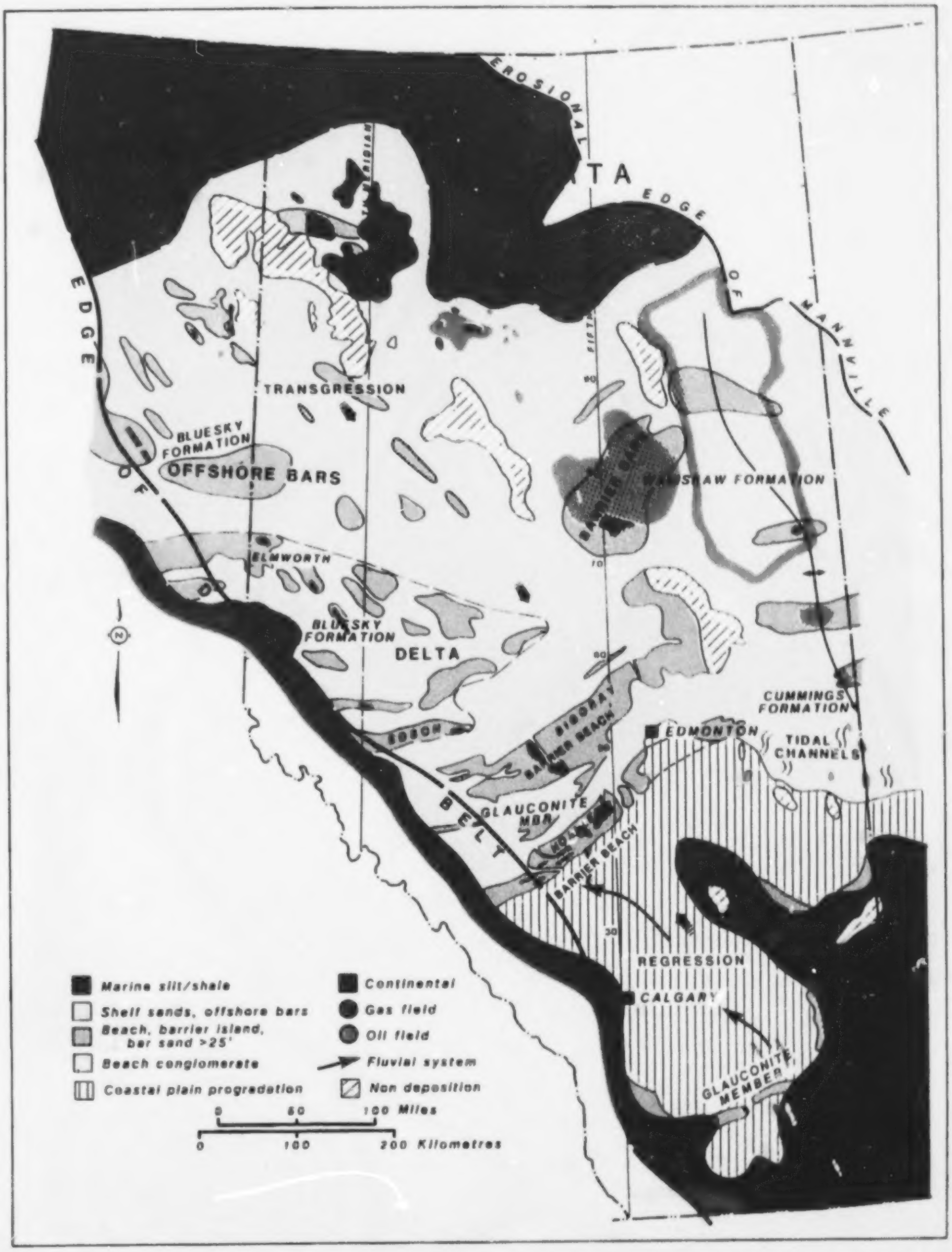

EROSIONAL EDGE
TA
EDGE OF MANNVILLE
EDGE OF
BELT
MERIDIAN
TRANSGRESSION
BLUESKY FORMATION
OFFSHORE BARS
ELMWORTH
BLUESKY FORMATION
DELTA
BARRIER BARS
WABISKAW FORMATION
CUMMINGS FORMATION
TIDAL CHANNELS
EDMONTON
BIGORAY BARRIER BEACH
GLAUCONITE MBR
BARRIER BEACH
REGRESSION
CALGARY
GLAUCONITE MEMBER
Marine silt/shale
Shelf sands, offshore bars
Beach, barrier island, bar sand >25'
Beach conglomerate
Coastal plain progradation
Continental
Gas field
Oil field
Fluvial system
Non deposition
0
50
100 Miles
0
100
200 Kilometres

Figure 7. Paleogeography during initial transgression of the Clearwater Sea. (modified after Masters, 1985)

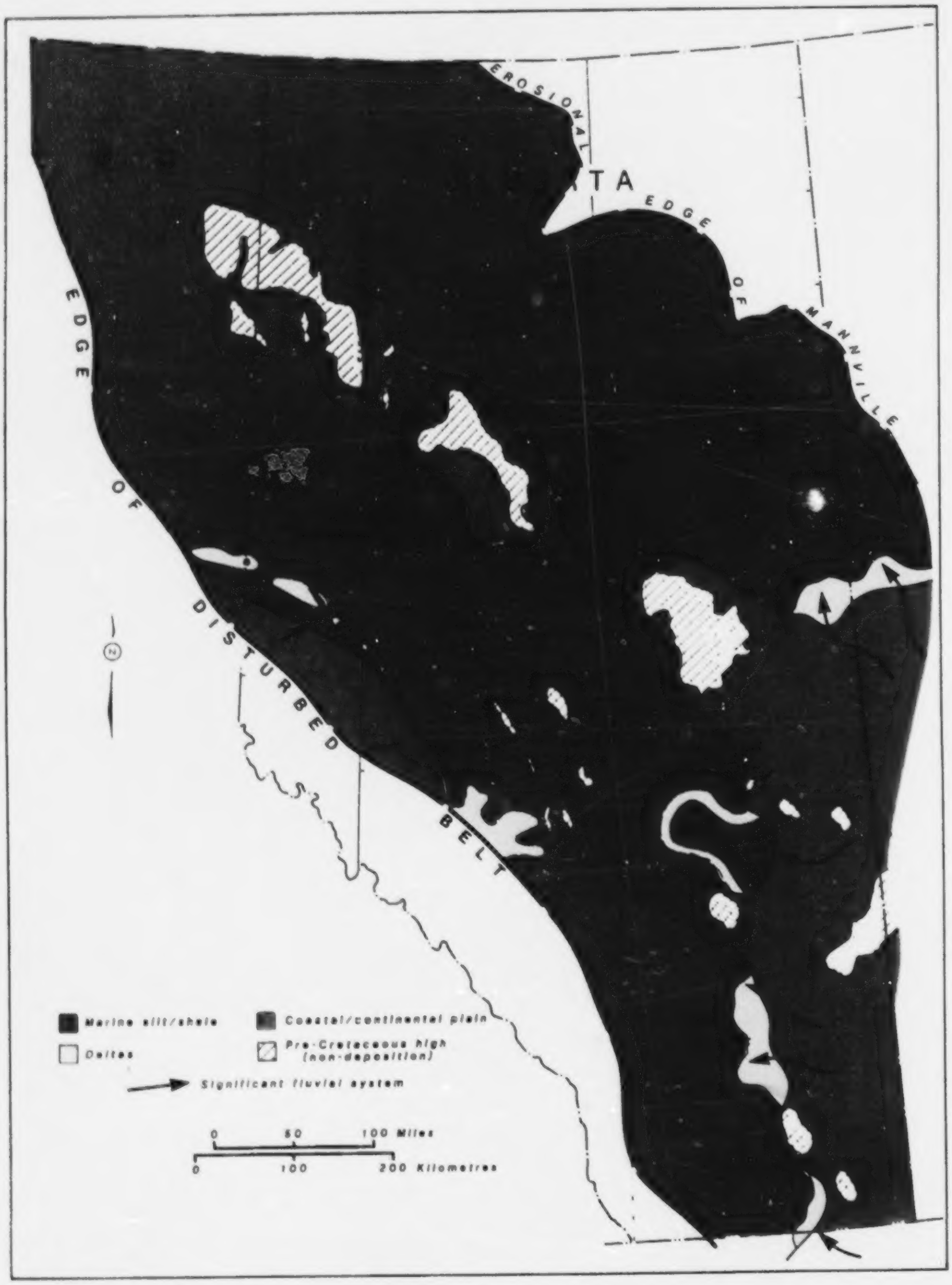

EROSIONAL
TA
EDGE
OF
MANNVILLE
EDGE
OF
DISTURBED
BELT
N
Marine silt/shale
Coastal/continental plain
Deltas
Pre-Cretaceous high (non-deposition)
Significant fluvial system
0
50
100 Miles
0
100
200 Kilometres

Figure 6. Paleogeography during Upper McMurray time.
(modified after Masters, 1985)

fluvial systems' depocenters begin to again prograde over the Middle McMurray Formation resulting in the distributary channels and associated facies of the Upper McMurray Formation (Figure 6). With renewed trangression in the early Albian (Figure 4), the area is submerged by the Clearwater Sea and in response, the Wabiskaw member of the overlying Clearwater Formation was deposited (Figures 7 and 8).

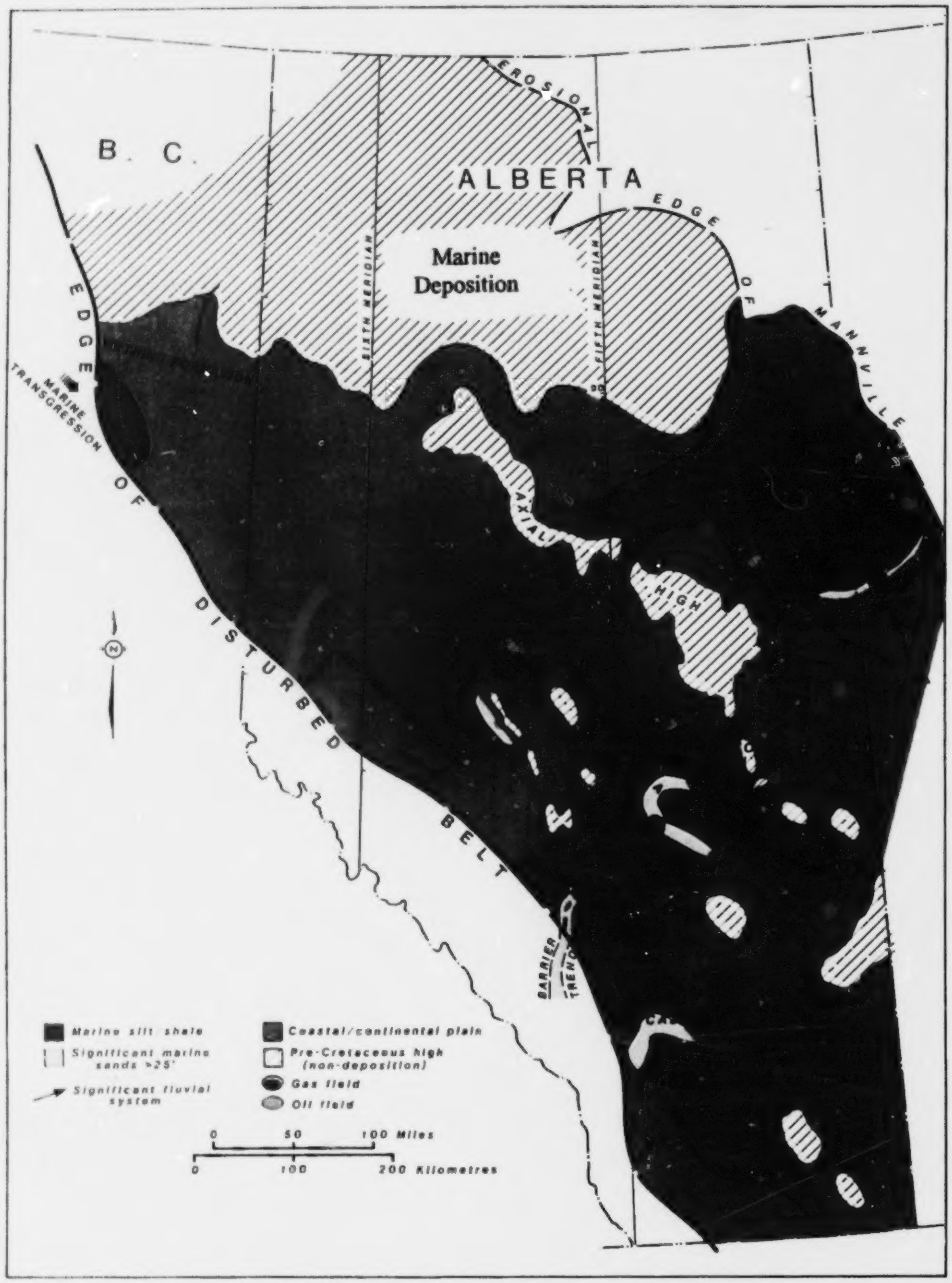

B. C.
ALBERTA
EROSIONAL EDGE OF MANNVILLE
Marine Deposition
SIXTH MERIDIAN
FIFTH MERIDIAN
EDGE OF DISTURBED BELT
MARINE TRANSGRESSION
AXIAL HIGH
BARRIER TREND
N
Marine silt shale
Significant marine sands >25'
Significant fluvial system
Coastal/continental plain
Pre-Cretaceous high (non-deposition)
Gas field
Oil field
0 50 100 Miles
0 100 200 Kilometres

Figure 5. Paleogeography during middle McMurray time.
(modified after Masters, 1985)

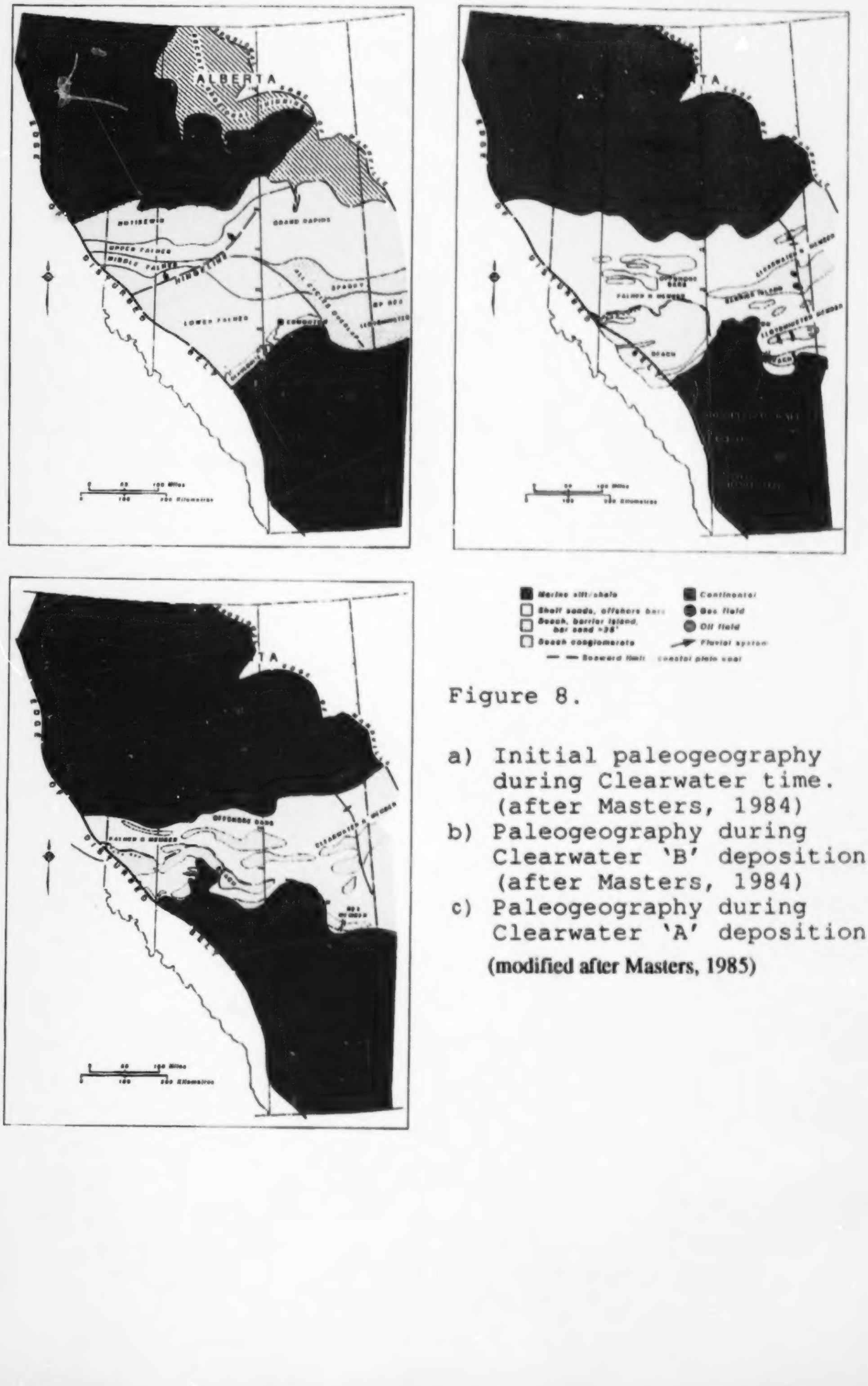

ALBERTA
EDGE OF DISTURBED BELT
NOTIKEWIN
GRAND RAPIDS
UPPER FALHER
MIDDLE FALHER
LOWER FALHER
SPARKY
EDMONTON
OFFSHORE BARS
FALHER B MEMBER
CLEARWATER B MEMBER
BEACH
0 50 100 Miles
0 100 200 Kilometres
Marine silt/shale
Continental
Shelf sands, offshore bars
Gas field
Beach, barrier island, bar sand >35'
Oil field
Beach conglomerate
Fluvial system
Seaward limit coastal plain coal

Figure 8.

a) Initial paleogeography during Clearwater time. (after Masters, 1984)
b) Paleogeography during Clearwater 'B' deposition. (after Masters, 1984)
c) Paleogeography during Clearwater 'A' deposition.
(modified after Masters, 1985)

General Geology

The McMurray Formation is clearly the depositional response to the transgression of the Bullhead Sea. As previously discussed, The Athabasca Channel is well defined and easily mapped on a regional scale. Deposition of the McMurray Formation has been divided into (Figure 9) the lower, middle, and upper members (Carrigy, 1966;Mossop and Flach, 1983; Keith *et al.*, 1987). It is important to note that what is termed "Upper McMurray" by one geologist in the northwest might be time equivalent to the "Middle McMurray Formation" in the southeast where this study takes place (Rennie, 1987). In the study area, the main paleovalley formed on the SubCretaceous Unconformity is filled through a progession from fluvial deposits to estuarine deposits. Upon filling of the paleovalley, further fluvial systems spread across the area feeding clastic shoreline systems to the northwest. These fluvial deposits are stratigraphically equivalent to the upper McMurray Formation marine shoreline deposits found to the northwest (Rennie, 1987). This system was subsequently flooded by the rise of the Clearwater Sea and the subsequent deposition of the northward prograding barrier bar systems referred to as the Clearwater 'C', 'B', and 'A' members in ascending chronostratigraphic

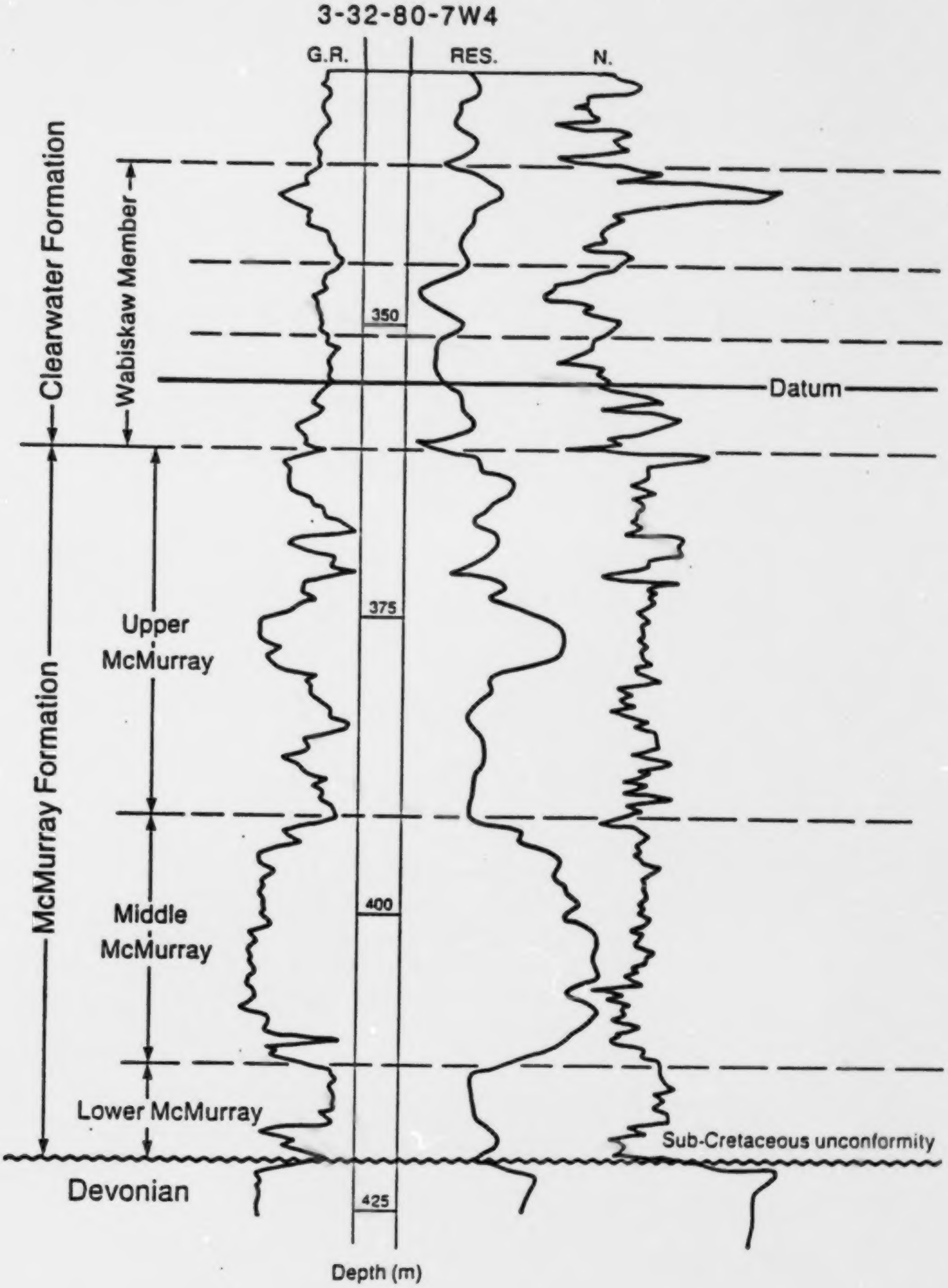


Figure 9. Type well subdividing McMurray Fm. in study area. (modified after Keith et al, 1987)

order.(Maher, 1989)

The type wells shown in Figures 9, 10, and 11 can be viewed in order to correlate the log picks in this study with others. As with all subsurface studies, internal consistency of stratigraphic correlations is of prime importance. These picks correspond with those of recent studies of the McMurray Formation to the northwest and the Clearwater Formation picks in the study by Maher, (1989). The Clearwater 'A' and Clearwater 'B' are the first and second major sand packages from the top respectively. The top of the Wabiskaw Member is picked as a relative low on the resistivity log, and represents a pervasive regional indicator. The McMurray Formation is then considered to be the first sand underlying the Wabiskaw Member, generally associated with a significant resistivity increase. The logs show a particularily good spontaneous potential response to gas in the Clearwater 'B' sands; with a small, but distinct, decrease of 5 mv at the gas/water interface in clean sands. The presence of gas throughout the interval is detected by the neutron-density crossover, although some instances were found where this criteria was not met as gas was produced from zones without crossover. These data were all considered to be quite reliably correlatable, markers which

McMurray Fm. Type Well

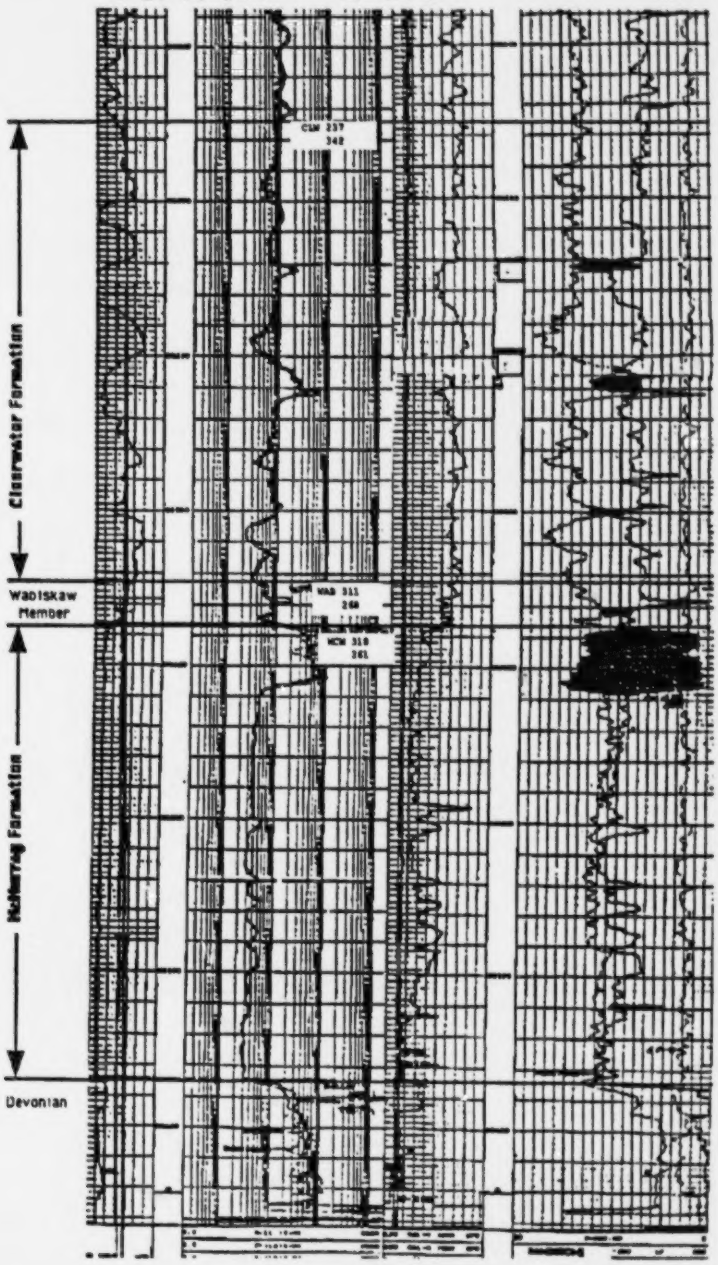


Figure 10. McMurray Formation type well showing typical tops.

Clearwater Fm. Type Well

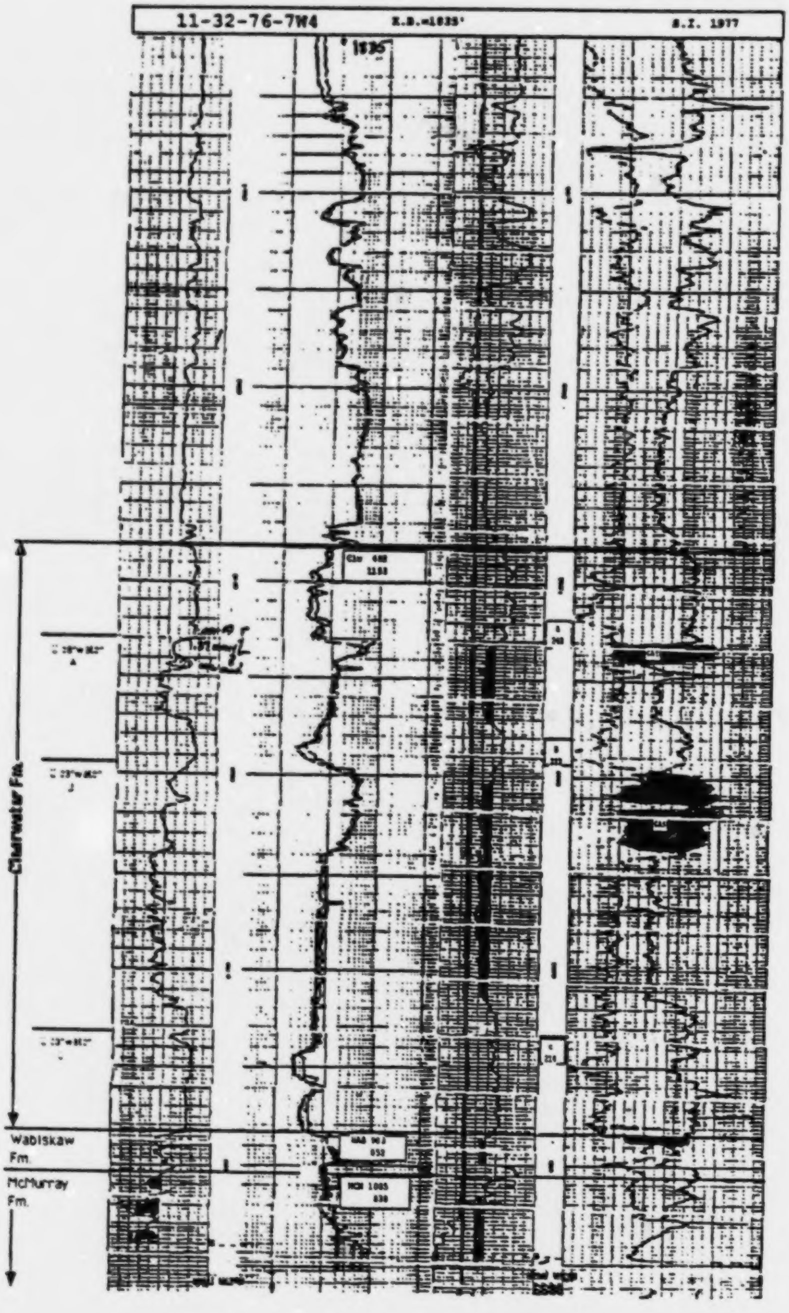


Figure 11. Clearwater Formation type well showing sand tops.

coincide to other studies, as well as, the Energy Resources Conservation Board's mineral rights interval designations.

McMurray Formation Facies Interpretation

Facies A : Interdistributary Mud / Levee Facies

This facies is comprised of light grey coloured mud deposited from suspension when currents have waned to the point where suspended material is no longer in equilibrium with current strength. Because of the varying pulses of flow energy, some thin bands of coarser material may be found associated within this facies. The facies is punctuated by syneresis cracks, characteristic of the fluctuating salinity of the system. *Planolites* are the most dominant of the abundant traces found in this facies, *Asterosoma, Skolithos, Arenicolites,* and *Diplocraterion* traces are also present in low proportions. Root traces that have been biodegraded to coal as well as siderite clasts can also be found (Figures 13a and 13b). No reservoir potential exists in this facies.

Facies B : Crevasse Splay Sands

Crevasse splay sand facies are comprised of trough cross-bedded and planar bedded, fine grained sands; no biogenic structures were found. This facies was deposited in response to channel currents branching out of the main channel and rapidly becoming unconfined,

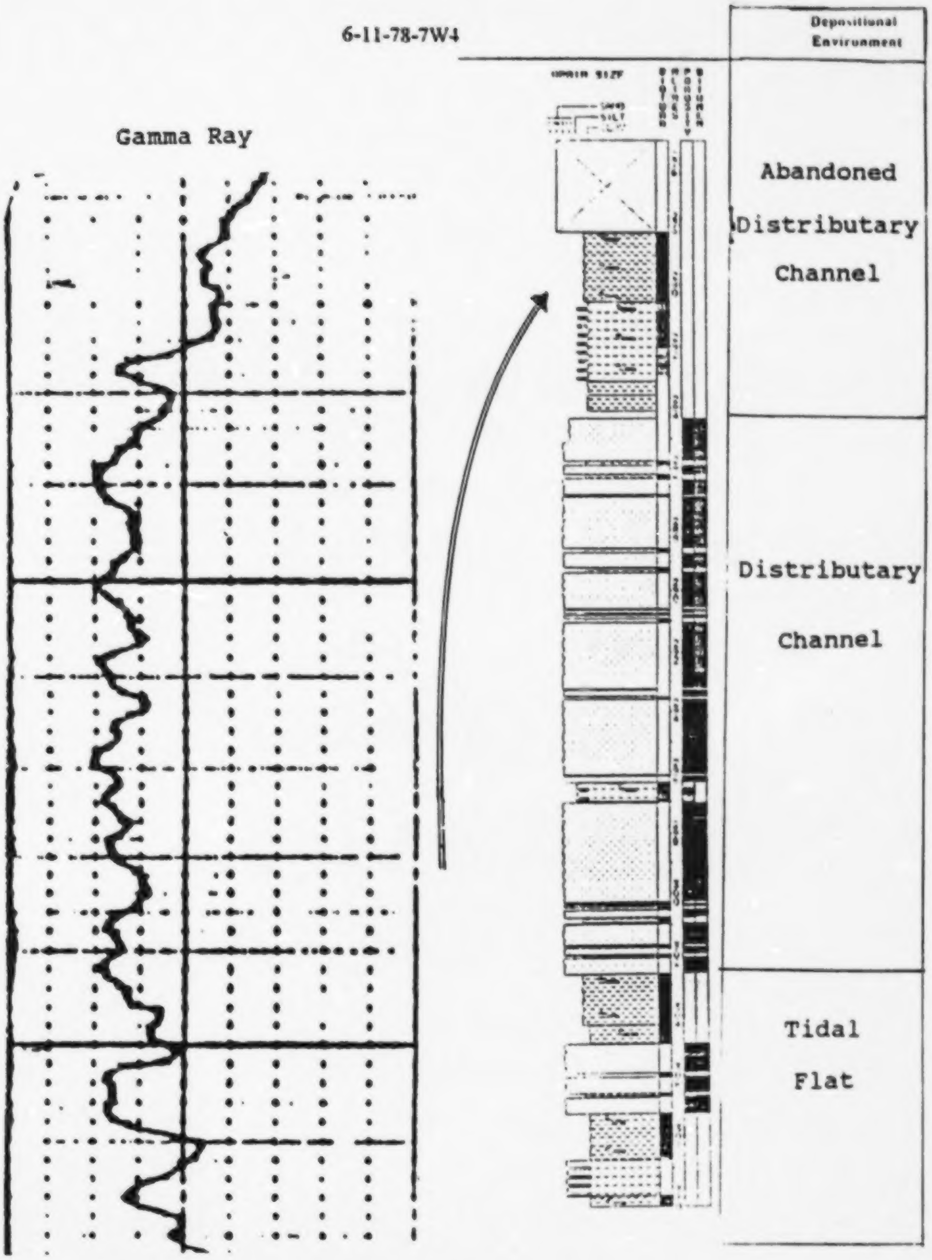


Figure 12. Log-Core correlation of Upper McMurray Formation

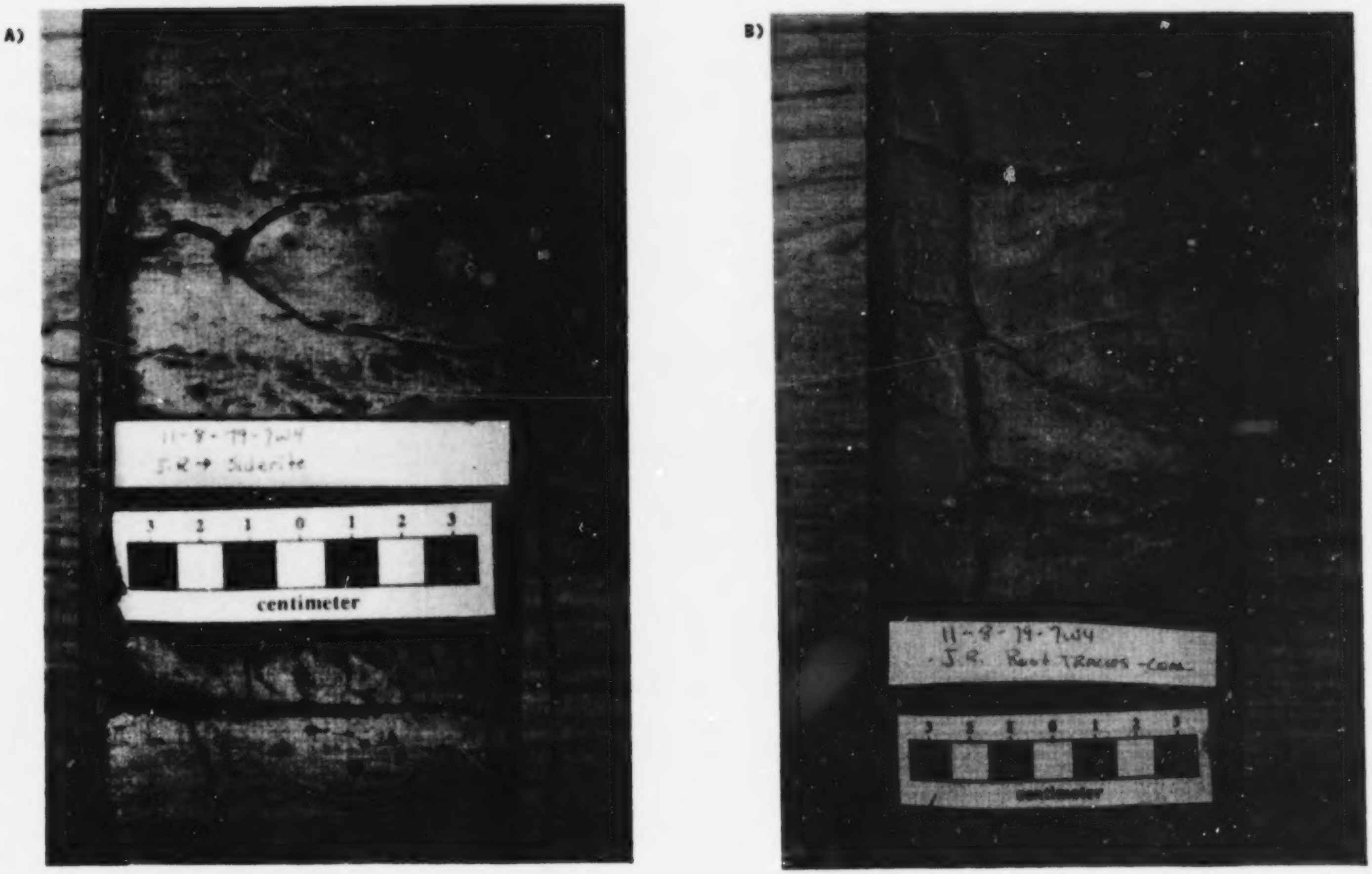

A)
11-8-79-7W4
S.R → Siderite
3 2 1 0 1 2 3
centimeter
B)
11-8-79-7W4
S.R. Root TRACES - coal
3 2 1 0 1 2 3
centimeter

Figure 13a) Siderite clast in well 11-8-79-7W4 @ 309.5 m. Interdistributary Bay Facies.
Figure 13b) Root trace replaced by coal; well 11-8-79-7W4 @ 308.5 m. Interdistributary Bay Facies.

resulting in rapid waning of the flow. The coarsening-up sequences are similar to distributary mouth bars but on a smaller scale. Crevasse splay sands, although porous and permeable, are not considered to be exploration targets due to limited lateral continuity and low recoverable gas reserves.

Facies C : Crevasse Splay Silt and Mud

The crevasse splay silts and muds are the lowermost member of the crevasse splay sequence. Small scale ripples can be found in the coarser sediments, although most of the deposits are planar laminated, interbedded silts and muds. The finest sediments exhibit *Planolites* and also display syneresis cracks (Figure 14a). The crevasse splay silts and muds are not reservoir facies.

Facies D : Abandoned Distributary Channel Facies

Abandoned distributary channel facies consist of interbedded mud,sand and silt and overlies the Upper Channel Fill Sand Facies. This further upward decrease in grain size is a reflection of decreasing flow energy related to channel abandonment. The facies is planar laminated and displays the ichnogenera *Planolites* and *Skolithos*. (Figure 14b). The facies is characterized by root traces, syneresis cracks, and

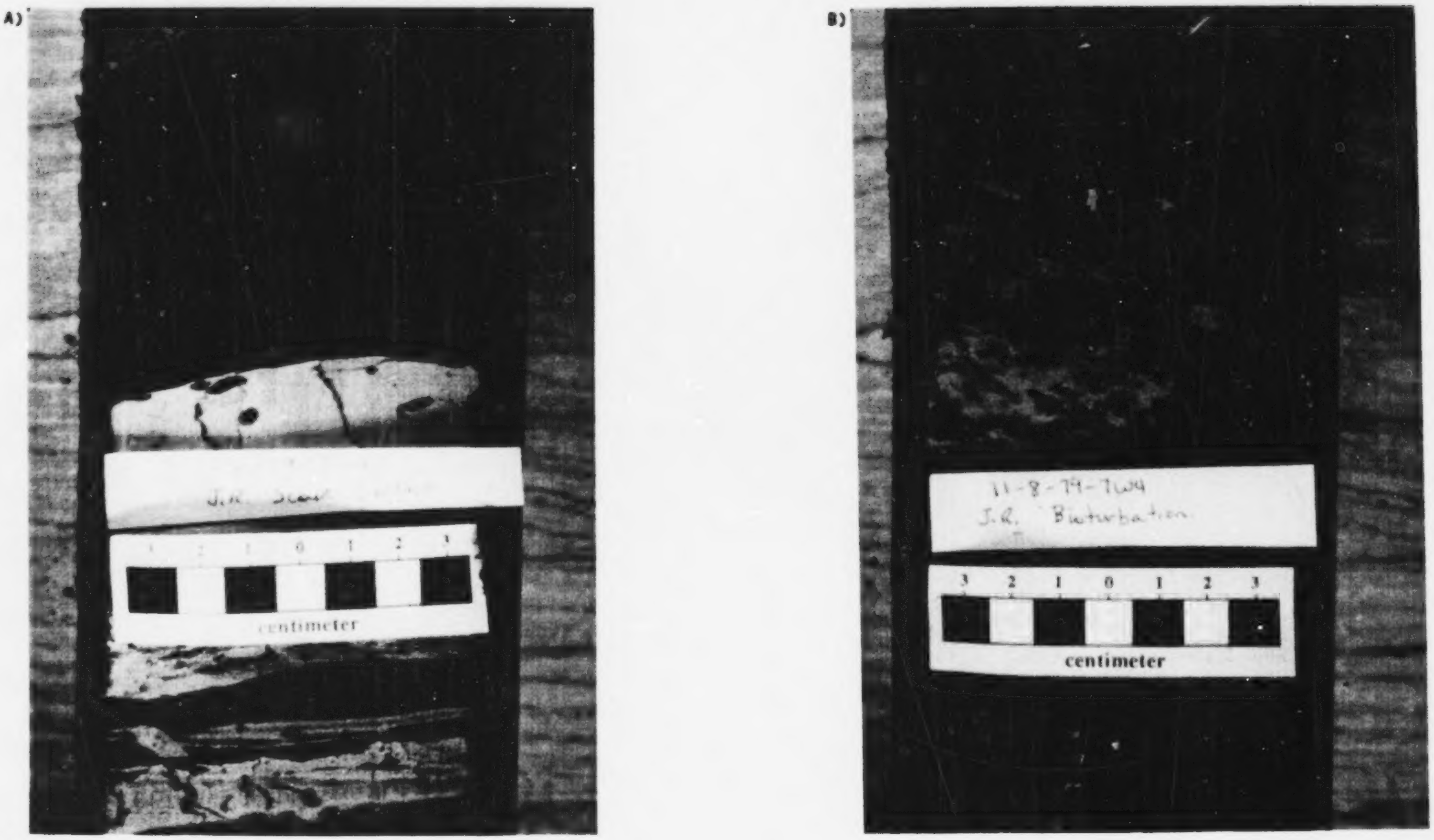

A)
J.R. Scour
3 2 1 0 1 2 3
centimeter
B)
11-8-79-7W4
J.R. Bioturbation
3 2 1 0 1 2 3
centimeter

Figure 14a) Syneresis cracks, scour surface, Planolites. Crevasse Splay Silt / Mud Facies
Figure 14b) Bioturbation; Planolites, Skolithos,well 11-8-79-7W4 Abandoned Estuarine Channel Facies.

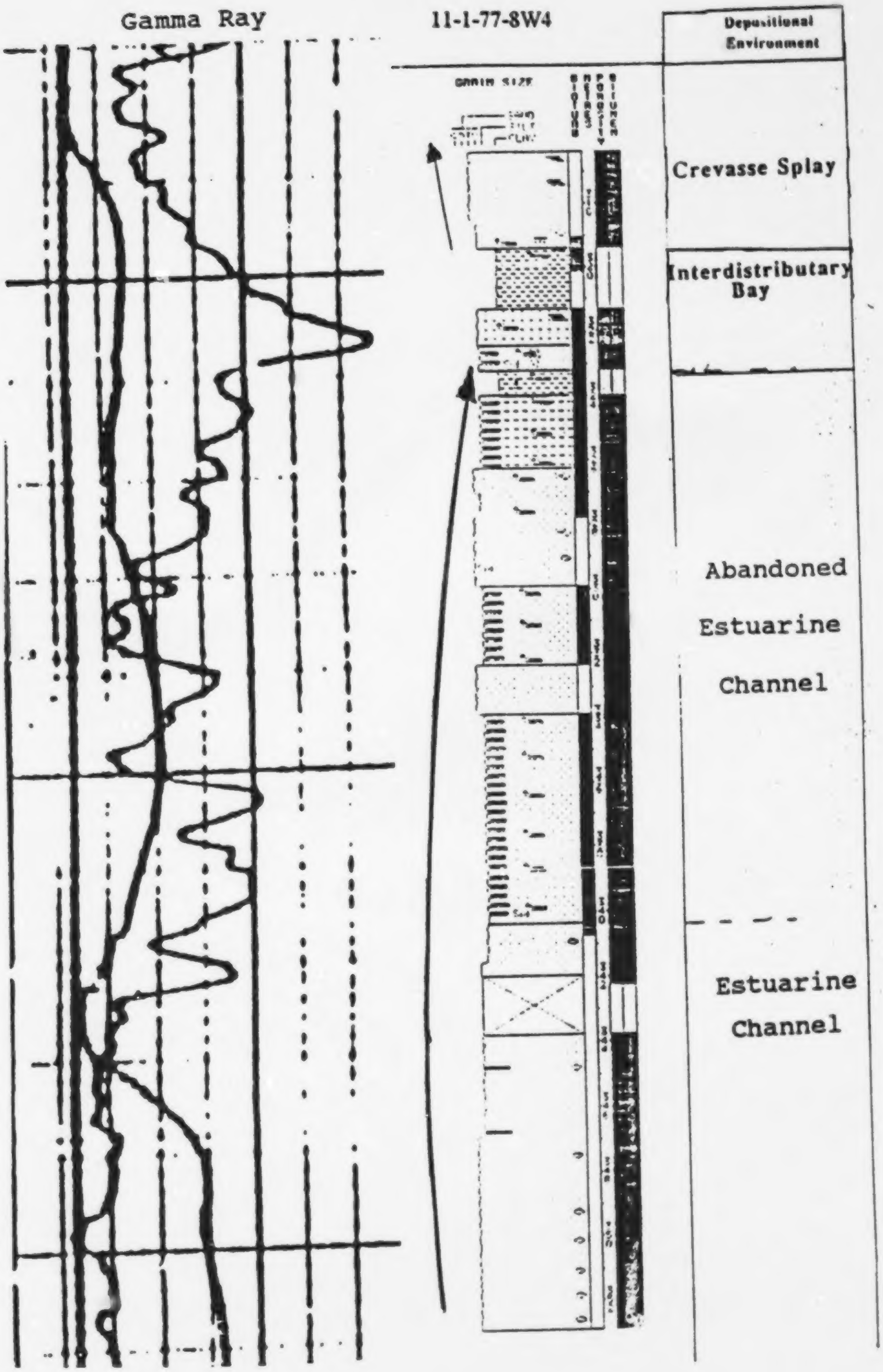

Gamma Ray
11-1-77-8W4
Depositional Environment
GRAIN SIZE
SAND
SILT
CLAY
BIOTURB
METERS
POROSITY
BITUMEN
Crevasse Splay
Interdistributary Bay
Abandoned Estuarine Channel
Estuarine Channel

Figure 15. Log-Core correlation of Upper-Middle McMurray Formation.

siderite clasts; violent soft-sediment deformation is present in response to rapid flooding and dewatering of the clays (Figures 16a and 16b). The overall fining upwards is found to be gradational with overlying muds. No reservoir potential is assigned to this facies.

Facies E : Upper Distributary Channel Fill

The Upper Channel Fill Facies is the uppermost sand in the channel fill sequence. It is a well sorted, fine to very fine grained sand. Ripple structures reflect the upwardly waning current throughout the channel fill sequence as does the increasing abundance of clay drapes. Biogenic structures are absent in the sand. This facies, although slightly less desirable than the lower channel fill facies, is considered a good reservoir rock.

Facies F : Intermediate Distributary Channel Fill

The intermediate channel fill is a well sorted, trough cross-bedded, fine grained sand. This facies overlies the Basal Channel Fill facies in the channel fill sequence. The facies lacks biogenic structures and clay drapes averaging 3-20 mm are found. It is considered a superb reservoir rock.

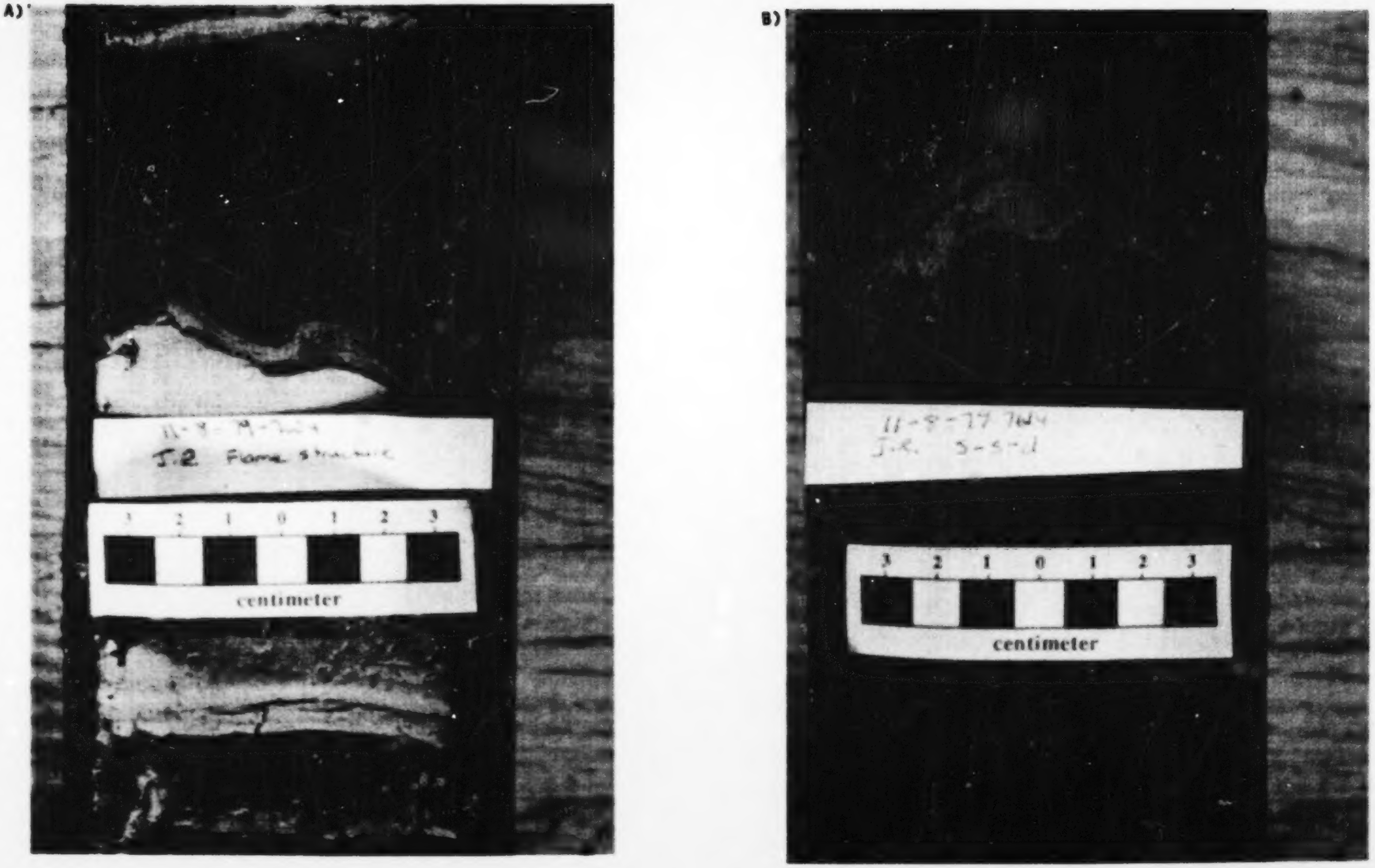

A)
B)
3 2 1 0 1 2 3
centimeter
3 2 1 0 1 2 3
centimeter

Figure 16a) Flame structure @ 307.8 m; well 11-8-79-7W4. Abandoned Estuarine Channel Facies.
Figure 16b) Soft-Sediment Deformation @ 308 m; well 11-8-79-7W4 Abandoned Estuarine Channel Facies.

Facies G : Basal Distributary Channel Fill

The basal channel fill is a well sorted, planar bedded, medium - fine grained sand. Rip-up clasts are occassionally observed and biogenic structures are absent from this facies, It overlies the Massive Channel Fill, (when present). The facies is an excellent reservoir rock.

Facies H :Massive Basal Distributary Channel Fill

This facies is a well sorted, medium grained sand that lacks any apparent structure. It appears to be the lowermost channel fill, but is not always present. Rip-up clasts are commonly present. Biogenic structures are absent and the facies is considered excellent reservoir rock.

Facies I : Delta Marsh / Tidal Flats

The delta marsh consists of interbedded mud, sand and silt, punctuated by small tidal creek deposits. The facies is planar laminated and displays some burrowing. *Planolites* is the most dominant trace found in this facies, *Asterosoma, Skolithos, Arenicolites,* and *Diplocraterion* are also present in low densities. Rooting has occurred where subaerial exposure has allowed vegetation to grow. Root traces that have been transformed to coal, and siderite clasts are also

McMurray Fm. Sedimentary Facies

Facies	Lithology	Sedimentary Structures	Biogenic Structures	Log Signature
A:Interdistributary Bay Muds	light grey mud small discontinuous silt lenses, organics/coal siderite clasts.	suspension deposition planar laminated small ripples in sands Syneresis cracks	*planolites* abundant, *Diplocraterion* *Asterosoma*, *Skolithos*, *Arenicolites*, Root traces,	shale with small, erratic sands, generally coarsen upwards
B: Crevasse Splay Sands	fine grained Sand	trough x-beds; planar bedding occassionally	none	coarsening upwards
C: Crevasse Splay silts and mud	intebedded silt and light grey mud	some small scale ripples mud-planar laminated	*planolites*	coarsening upwards
D:Abandoned Distributary Channel Facies	Interbedded mud/silt organics/coal siderite clasts.	planar laminated Syneresis cracks mud is suspension deposition	*planolites*, *Skolithos*, *Asterosoma*, *Arenicolites* *Diplocraterion*, Root Traces	fining upwards
E: Upper Distributary Channel Fill	fine - very fine grained sand well sorted	small scale current ripples clay drapes	none	fining upwards
F: Intermediate Distributary Channel Fill	fine grained sand well sorted	trough x-bedded clay drapes	none	fining upwards
G:Basal Distributary Channel Fill	medium - fine grained sand well sorted	planar bedded rip-up clasts	none	fining upwards
H:Massive Basal Distributary Channel Fill	medium grained sand well sorted	massive rip-up clasts	none	fining upwards
I: Delta Marsh / Tidal Flats	Interbedded mud Silt / Sand organics/coal siderite clasts.	mud-planar laminated Syneresis cracks sand-ripples	*planolites*, *Skolithos*, *Asterosoma*, *Arenicolites* *Diplocraterion*, Root Traces	shale with small, erratic sands, generally coarsen upwards

Table 2. Summary of McMurray Fm. Sedimentary Facies

observed. The facies contains abundant syneresis cracks, characteristic of the fluctuating flooding and evaporation in the system. The tidal creek deposits are less than 5 m in thickness and show fining up profiles with the same biogenic characteristics as the surrounding finer grained deposits. The delta marsh deposits are of little economic importance as reservoir qualities are poor to nonexistant.

Facies J : Abandoned Estuarine Channel Facies

Abandoned estuarine channel facies consist of interbedded mud,sand and silt and overlies the Upper Channel Fill Sand Facies. This further upward decrease in grain size is a reflection of decreasing flow energy related to channel abandonment. The facies is planar laminated and exhibits the following trace fossils; *Planolites*, *Skolithos*, *Asterosoma*, *Diploctaterion*, and *Arenicolites*, as well as, the presence of root traces, syneresis cracks, and siderite clasts. The overall fining upwards is found to be gradational with overlying muds and underlying sands.

Facies K : Upper Estuarine Channel Fill

The upper estuarine channel fill facies is the uppermost sand in the channel fill sequence. It is a

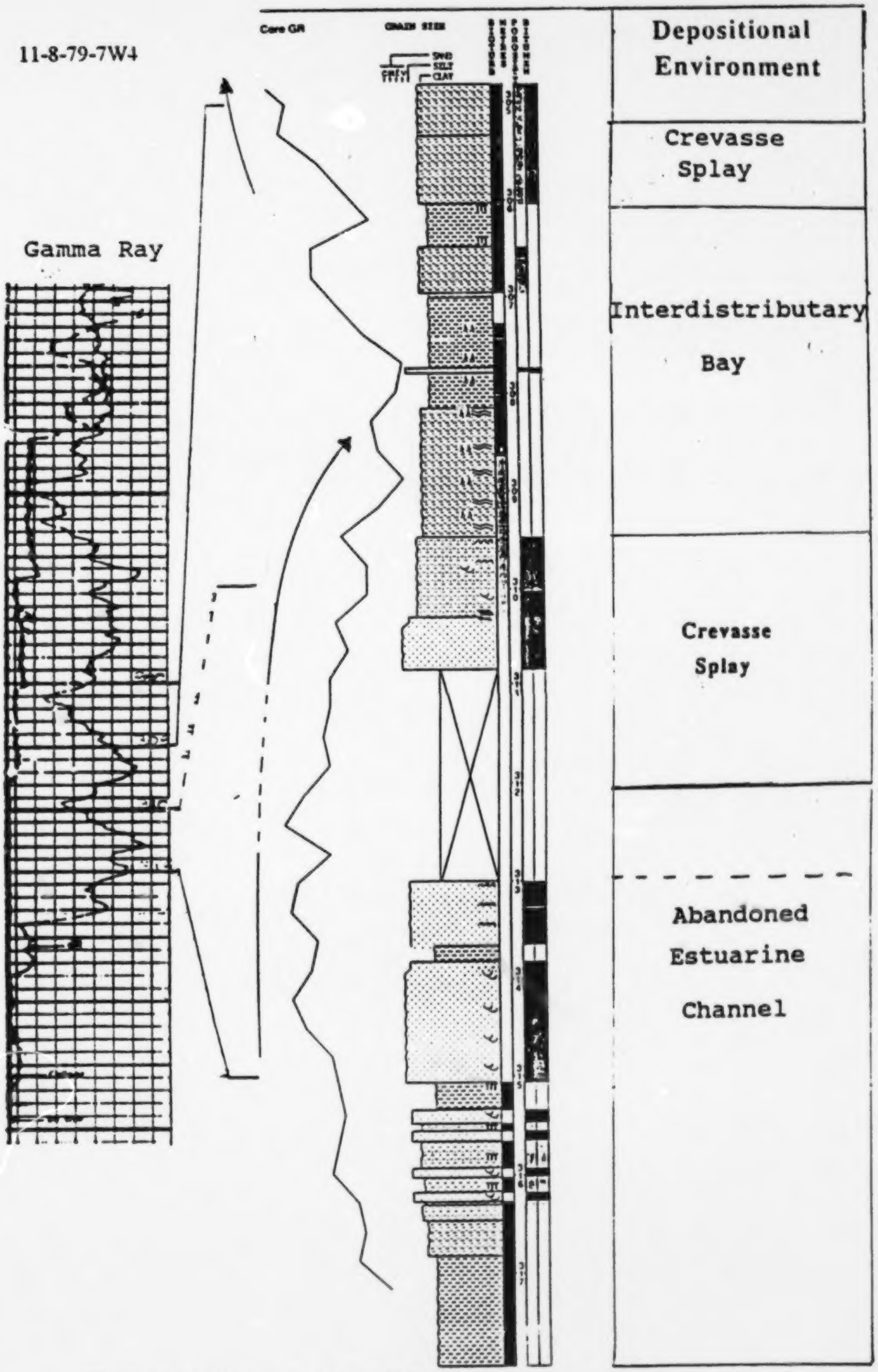

11-8-79-7W4
Gamma Ray
Core GR
Grain Size
Depositional Environment
Crevasse Splay
Interdistributary Bay
Crevasse Splay
Abandoned Estuarine Channel

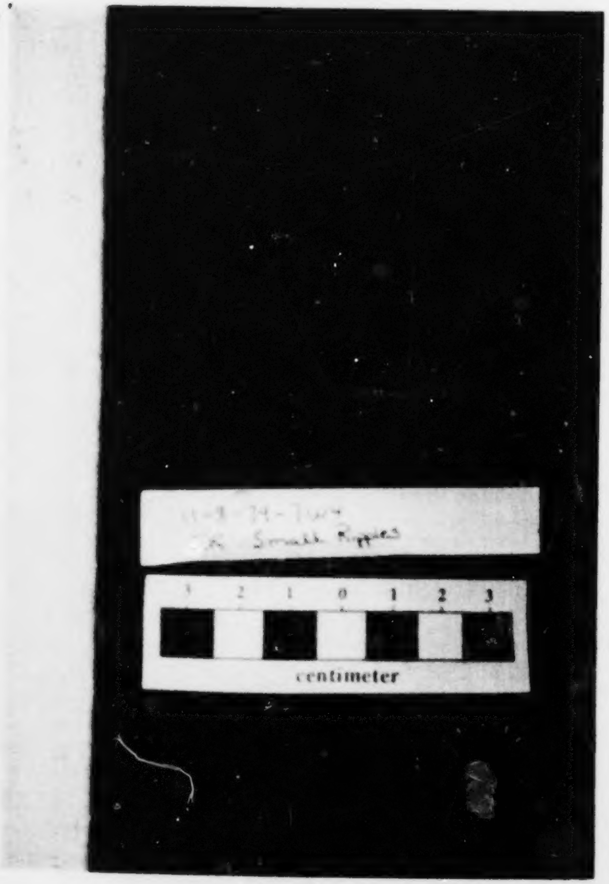
Figure 17. Log-Core correlation of Middle McMurray Formation

well sorted, fine to very fine grained sand. Ripple structures reflect the upwardly waning current throughout the channel fill sequence as does the increasing abundance and thickening of shale breaks. Prograding ripple sets are a common occurence (Figure 18a), a few *Palaeophycus* are seen in the sand and *Planolites* can be found to have penetrated the larger shale breaks. The estuarine channels are found to contain considerably higher occurences of biogenic components. This facies, although slightly less desirable than the lower channel fill facies, is considered a good reservoir rock.

Facies L : Intermediate Estuarine Channel Fill

The intermediate estuarine channel fill is a well sorted, trough cross-bedded, fine grained sand. The presence of mud-couplets and tidal bundles are evidence of tidal influence (Figures 18b and 20a). These tidal bundles are the main differentiating tool between distributary channels and estuarine channels (Smith, 1988). This facies overlies the Basal Channel Fill facies in the channel fill sequence. This facies lacks biogenic structures and clay drapes averaging 3-20 mm are found. It is an excellent reservoir rock.

A)


11-8-79-7W4
J.R. Small Ripples
3 2 1 0 1 2 3
centimeter

B)

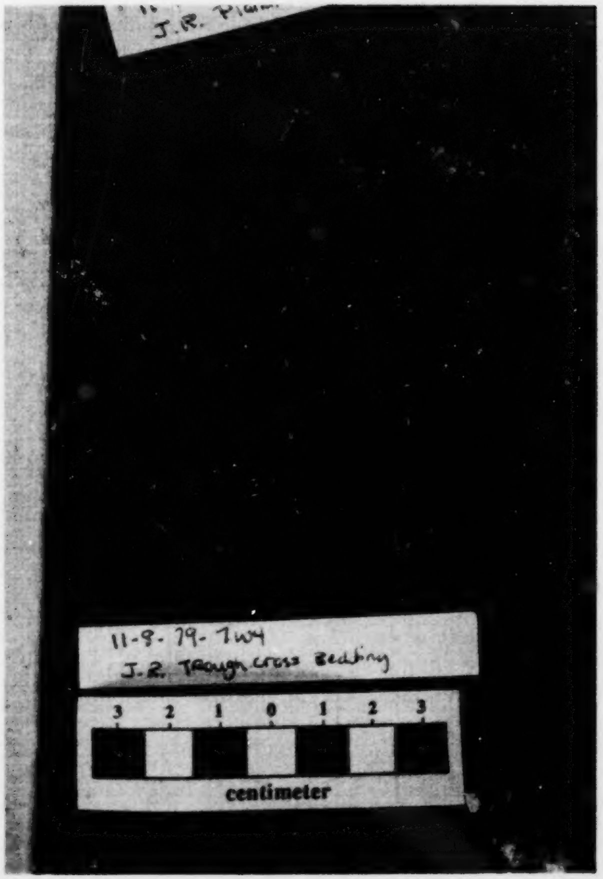

J.R. Plan
11-8-79-7W4
J.R. Trough cross Bedding
3 2 1 0 1 2 3
centimeter

Figure 18a) Prograding small-scale ripples ~ 313 m; well 11-8-79-7W4. Upper Estuarine Channel Fill Facies

Figure 18b) Small scale ripples, wave & tidal influence?, trough x-beds above ~ 314.5 m; well 11-8-79-7W4. Intermediate Estuarine Channel Fill Facies

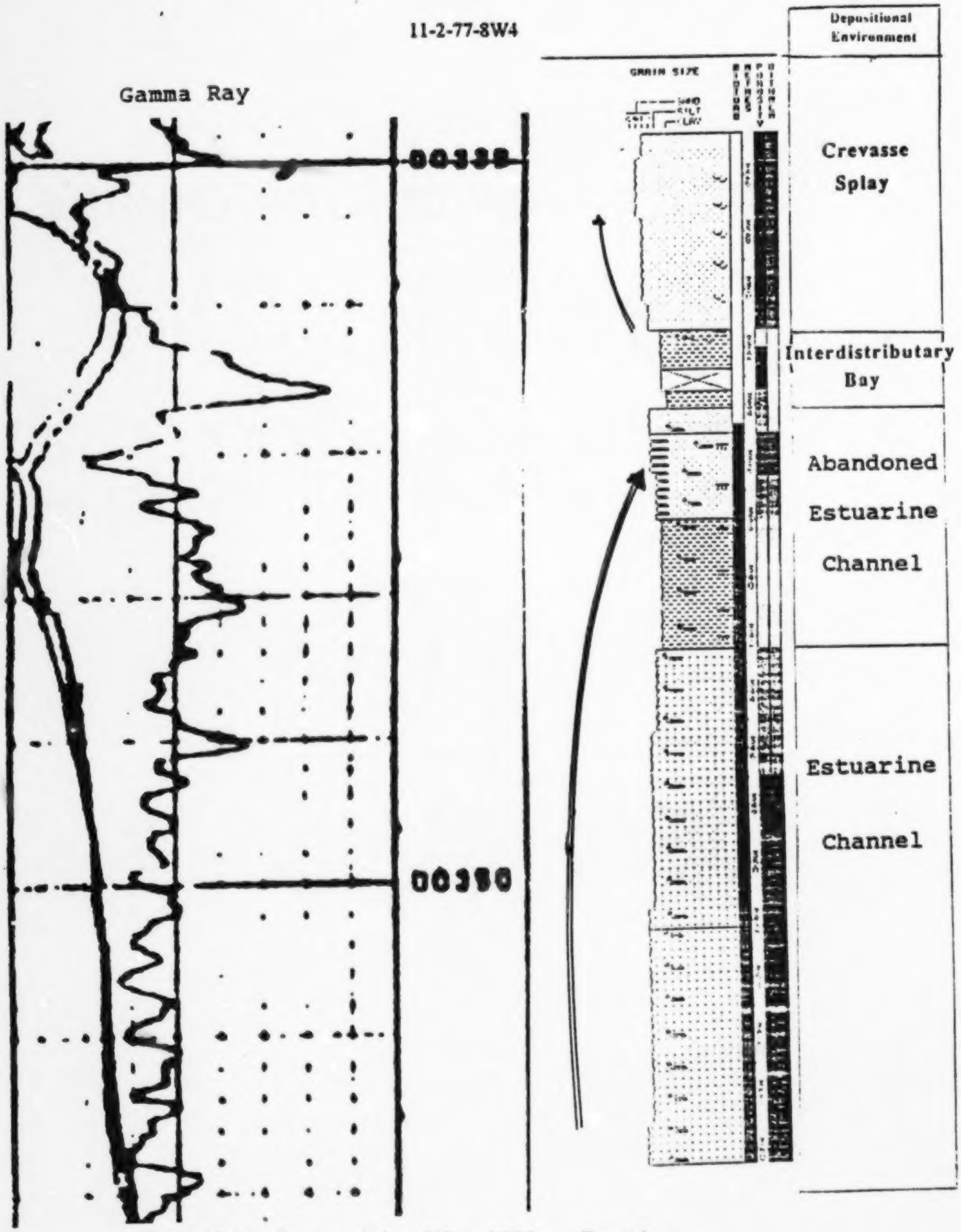
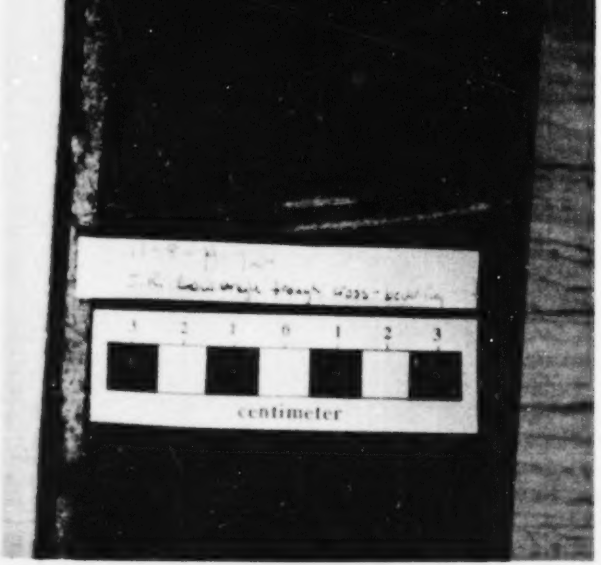


Figure 19. Log-Core correlation of Upper McMurray Formation

A)

B)


3 2 1 0 1 2 3
centimeter

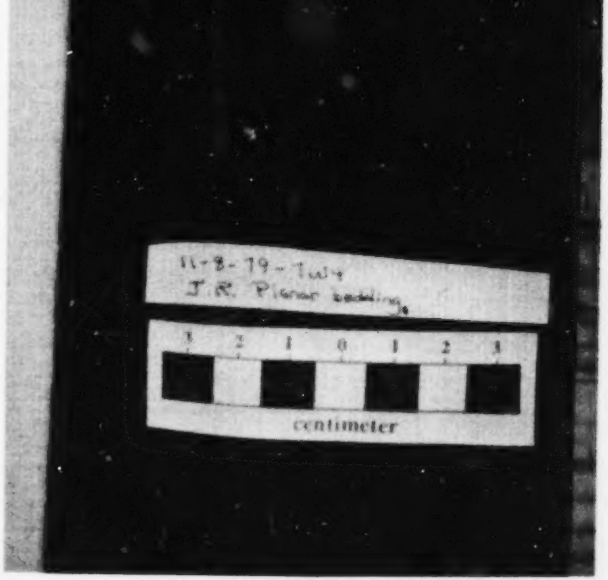

11-8-79-7w4
J.R. Planar bedding
3 2 1 0 1 2 3
centimeter

Figure 20a) Trough x - bedding @ 315 m; tidal influence! Well 11-8-79-7W4. Intermediate Estuarine Channel Fill
Figure 20b) Planar bedding @ 317 m; tidal influence! Well 11-8-79-7W4. Basal Estuarine Channel Fill

Facies M : Basal Estuarine Channel Fill

The basal channel fill is a well sorted, planar bedded, medium - fine grained sand (Figure 20b). There is the impression that tidal processes have influenced deposition, reactivation surfaces and some subordinate flow structures were observed. Constantly varying flow structures are prevalent. Rip-up clasts are occassionally seen in addition to siderite nodules; biogenic structures are absent from this facies. When present, it overlies the massive channel fill. The facies is an excellent reservoir rock.

Facies N : Massive Basal Estuarine Channel Fill

This facies is a well sorted, medium grained sands that lacks any apparent structure. It appears to be the lowermost channel fill, but is not always present. Rip-up clasts are commonly present and lag deposits, althoough not observed in this study, would be expected. Biogenic structures are absent and the facies is considered excellent reservoir rock.

Facies O : Fluvial Facies

The fluvial facies described is the lowermost deposit of the McMurray Formation and is often not deposited. When present, it follows the typical fining upwards sequence displaying corresponding

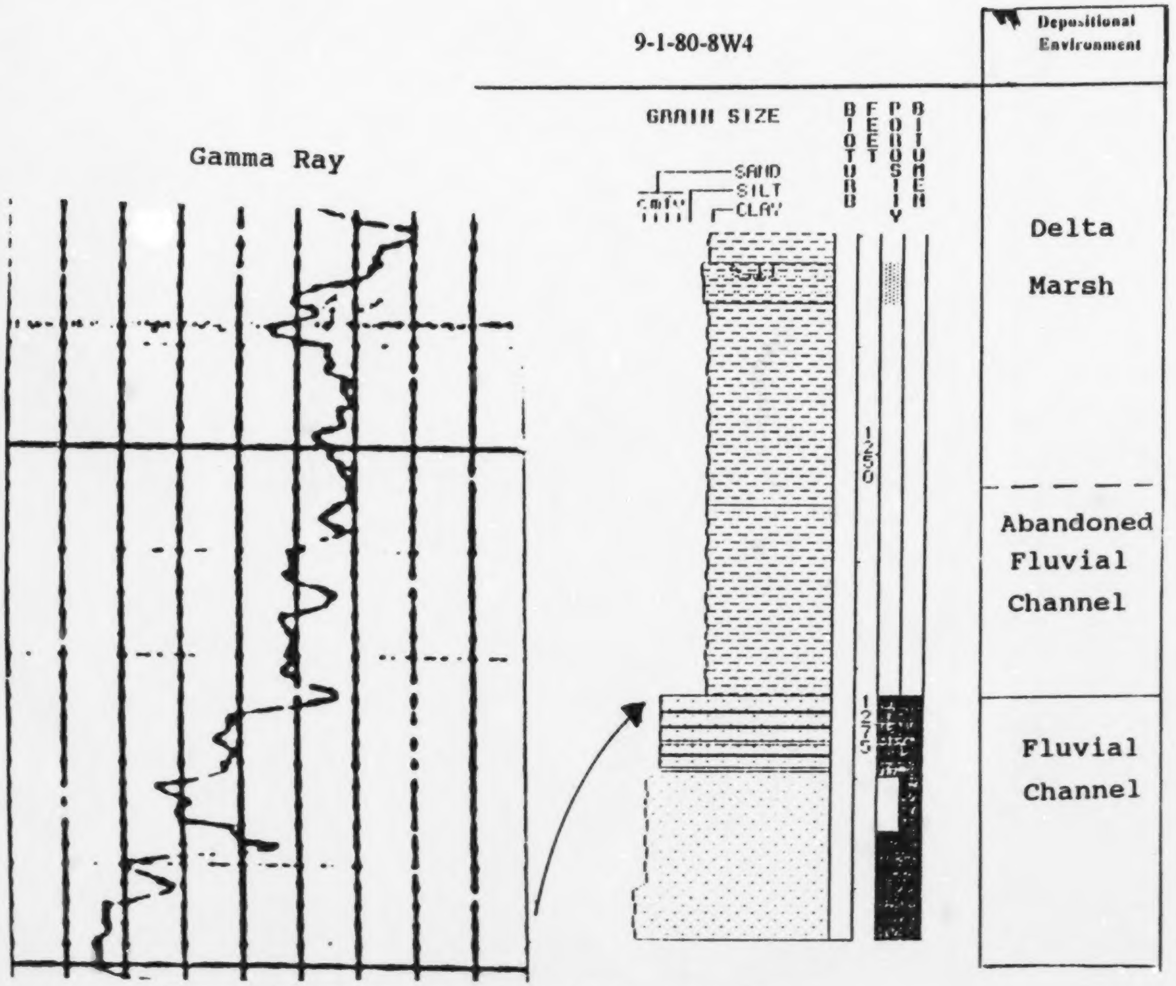


Figure 21. Log-Core correlation of Lower McMurray Formation

structure and grain size trend for a decreasing flow energy deposit. To briefly describe it, there is a transition from a lag deposit, to planar bedded sands, to cross-bedded sands, to small scale ripples, to planar laminations and finally the uppermost unit is a mud deposited from suspension;grain size decreasing constantly upwards. This sequence, of course, is commonly interrupted and missing some sections. The core chosen to represent this progression unfortunately is saturated to the extent that recognition of decreasing flow regime structures is disguised. The grain size in the 9-1-80-8W4 core does show the traditional transition from fine grained sand, to very fine grained sand, to silt and finally the suspension mud cap. A few rip-up mud clasts are also seen in the core. Although this unit has reservoir potential, it is generally not at a sufficient structural elevation to reservoir natural gas.

McMurray Fm. Sedimentary Facies (Con't)

Facies	Lithology	Sedimentary Structures	Biogenic Structures	Log Signature
J:Abandoned Estuarine Channel Facies	Interbedded mud/silt organics/coal siderite clasts.	planar laminated Synerosis cracks mud is suspension deposition	*planolites*, *Skolithos*, *Asterosoma*, *Arenicolites* *Diplocraterion*, Root Traces	fining upwards
K: Upper Estuarine Channel Fill	fine - very fine grained sand shale breaks organics in troughs	small scale current ripples, shale breaks prograding ripples combined flow ripples tidal bundles	sand-*Paleophycus* shale-*Planolites*	fining upwards
L: Intermediate Estuarine Channel Fill	fine grained sand well sorted	trough x-bedded tidal bundles clay drapes rip-up clasts	sand-*Paleophycus* shale-*Planolites*	fining upwards
M:Basal Estuarine Channel Fill	medium - fine grained sand siderite nodules	planar bedded rip-up clasts constantly varying flow	none	fining upwards
N:Massive Basal Estuarine Channel Fill	medium grained sand siderite nodules	massive rip-up clasts	none	fining upwards
O:Fluvial Facies	fining upwards sequence from m.g. sand to mud siderite and organics near top of sequence	waning flow from planar bedding to small scale ripples and suspension deposition. rip-ups inlower units	bioturbation near top of sequence *planolites*, *Skolithos*, *Asterosoma*, *Arenicolites* *Diplocraterion*, Root Traces	fining upwards

Table 3. Summary of McMurray Fm. Sedimentary Facies (Con't)

Clearwater Formation Facies Interpretation

Facies P : Marine Shale

This facies is comprised of light grey coloured mud deposited from suspension when energy has waned to the point where suspended sediment is no longer in equilibrium will flow energy. The marine shale deposit is massive in appearance, and is devoid of biogenic structures at a visual level. The facies holds no reservoir potential.

Facies Q : Nearshore Bar Facies

This facies is a sequence of fining upwards cycles. The sands are well sorted, and grade from fine grained sand to silt. The unit is devoid of biogenic or sedimentary structures, appearing massive in core. The facies is an excellent reservoir rock.

Facies R : Wabiskaw Transgressive Lag

The Wabiskaw Member of the Clearwater Formation is a fine grained glauconitic sand devoid of sedimentary stuctures. What appeared to be large *Skolithos* or perhaps *Macronichnus* were present. The facies, because of its maximum thickness of 4 m sand in the study area, is a relatively insignificant exploration target, despite good reservoir qualities.

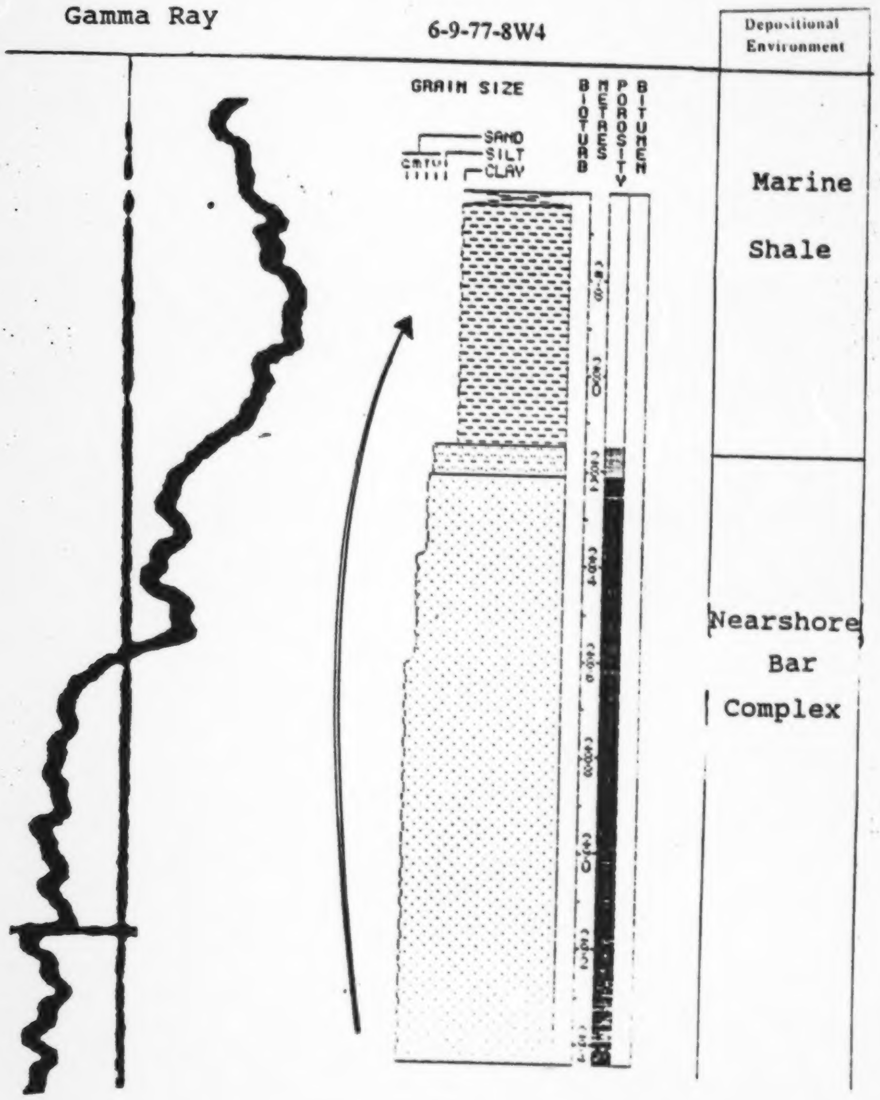

Gamma Ray
6-9-77-8W4
Depositional Environment
GRAIN SIZE
SAND
SILT
CLAY
BIOTURB
METRES
POROSITY
BITUMEN
Marine Shale
Nearshore Bar Complex

Figure 22. Log-Core correlation of Clearwater 'B' Sand

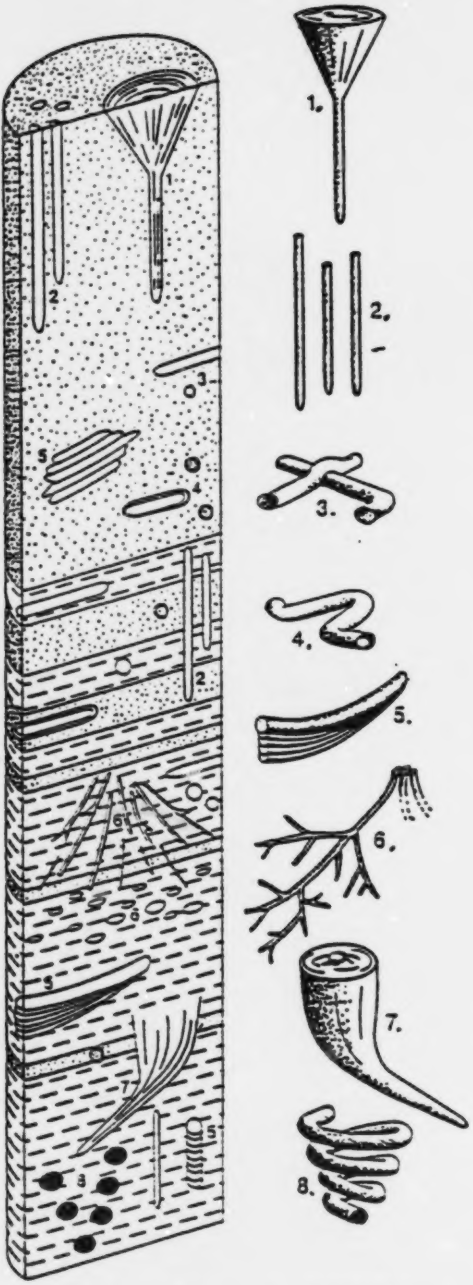
Clearwater Fm. Sedimentary Facies

Facies	**Lithology**	**Sedimentary Structures**	**Biogenic Structures**	**Log Signature**
P:Marine Shale	gy muds	maassive	none	less dense mud signature on gamma ray
Q:Nearshore Bar Facies	gradational fining upwards sequence f.g Ss - silt	massive	none	fining upwards
R:Wabiskaw Transgressive Lag	green, glauconite sand	massive	*Skolithos?* *Macronichnus?*	?

Table 4. **Summary of Clearwater Fm. Sedimentary Facies**

Ichnology

This section will focus on the ichnological aspects of the McMurray Formation; the Clearwater Formation is lacking significant ichnologic record. Trace fossils are a valuable tool for aiding in the interpretation of the McMurray Formation. They are generally found in the fine grained silts and muds in the form of *Skolithos, Arenicolites, Diplocraterion, Asterosoma,* and *Planolites* (Figures 24, 25, and 26). A study by Mattison (1987), to the northwest, interpreted to be further basinward, found an ichnological suite indicating a Middle McMurray Formation estuarine environment with increasing marine influence upwards, capped by fully marine Upper McMurray Formation deposits. Mattison found the most common traces to be *Planolites, Palaeophycus, Cylindricnus, Teichichnus,* and *Skolithos*; less commonly were *Ophiomorpha, Berguaria, Thalassinoides, Conichnus, Conostichus, Asterosoma, Monocraterion, Rosellia, and Gyrolithes*. Ranger and Pemberton (1988), investigated an area to the south at Primrose, once again finding Middle McMurray Formation estuarine deposits. They found a brackish water suite comprised of *Skolithos, Planolites, Cylindricnus,* in the sands and also *Teichichnus* in the shale; special mention of their

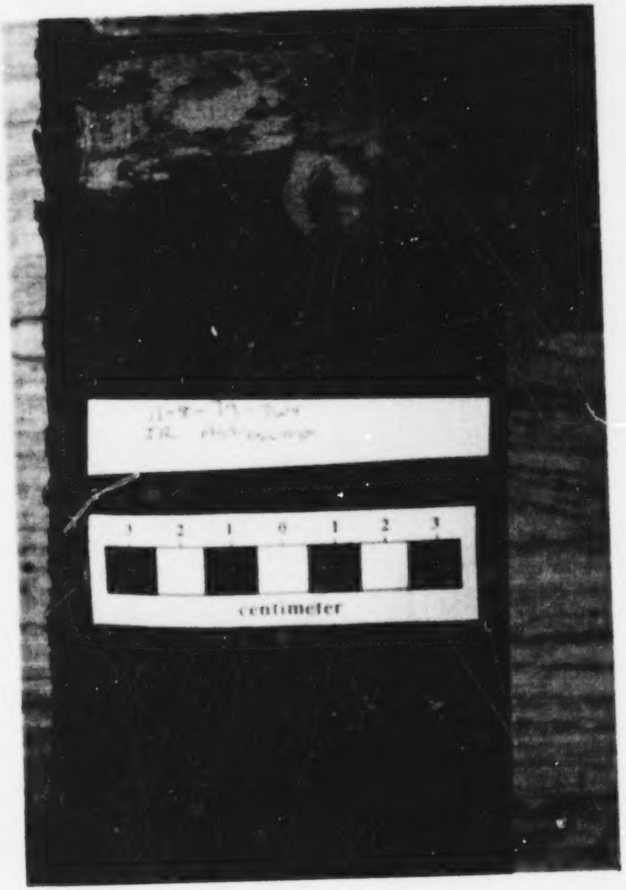


1. *Monocraterion*
2. *Skolithos*
3. *Planolites*
4. *Palaeophycus*
5. *Teichichnus*
6. *Chondrites*
7. *Rosselia*
8. *Gyrolithes*

Figure 23 McMurray Formation Impoverished Marine Trace Assemblage. (modified after Wightman et al, 1987)

abundance yet low diversity and small size is made to emphasize the stressed marine influence (Ranger and Pemberton, 1988). As Pemberton *et al.*, (1987), stated, the names of the individual traces are not as important as the general characteristics of the assemblage; a) low diversity, high intensity; b) typical marine traces of *Cruziana* and *Skolithos* Ichnofacies; c) non-specialized feeding patterns; and d) vertical and horizontal ichnofossils common to both *Cruziana* and *Skolithos* ichnofacies are characteristic of the impoverished marine assemblage and is utilized as another tool for interpreting depositional environment.

A)


11-8-79-7W4
J.R.
3 2 1 0 1 2 3
centimeter

B)

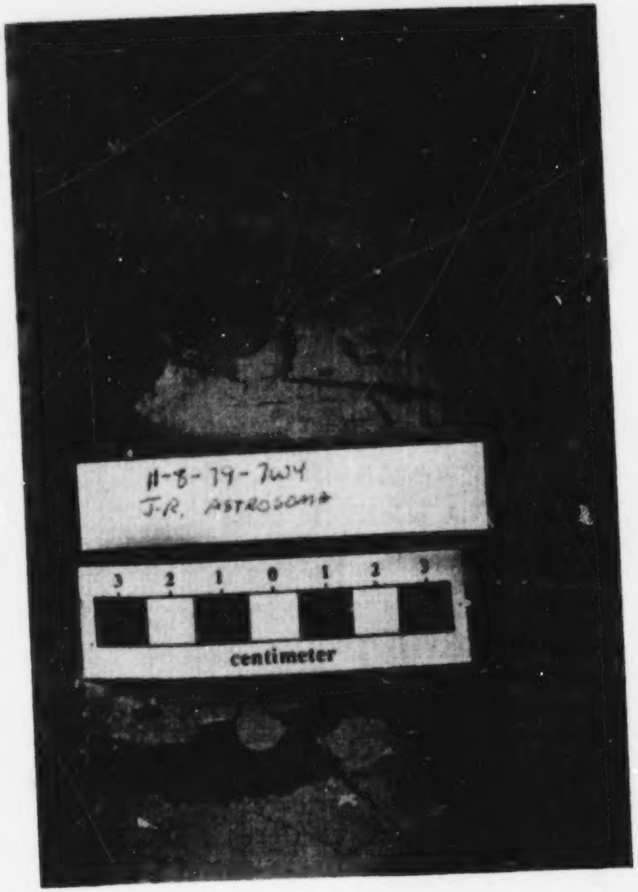
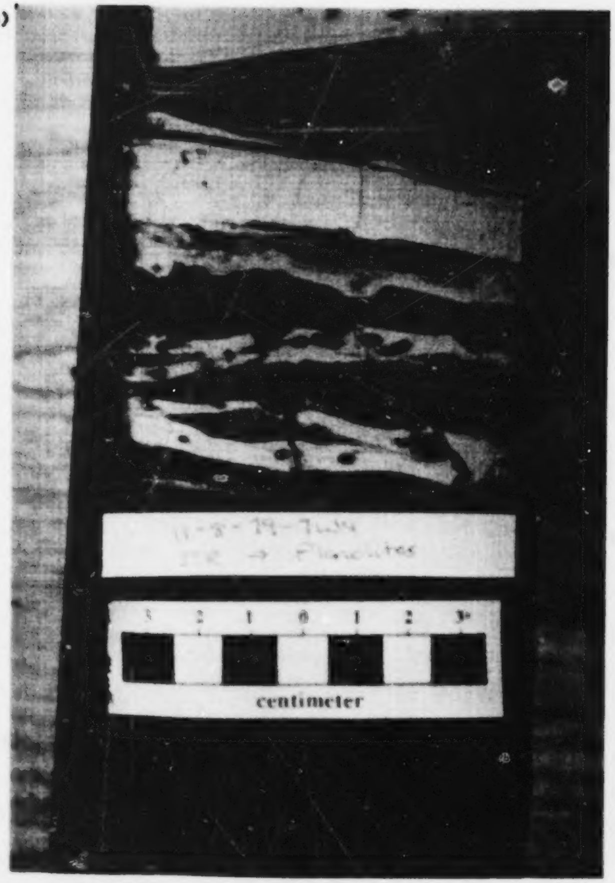

11-8-79-7W4
J.R. ASTROSOMA
3 2 1 0 1 2 3
centimeter

Figure 24a) Skolithos ~ 307 m; Well 11-8-79-7W4. Interdistributary Bay Facies.
Figure 24b) Asterosoma ~ 308 m; Well 11-8-79-7W4. Interdistributary Bay Facies.

A)


11-8-79-7W4
J.R. → Planolites
3 2 1 0 1 2 3
centimeter

B)

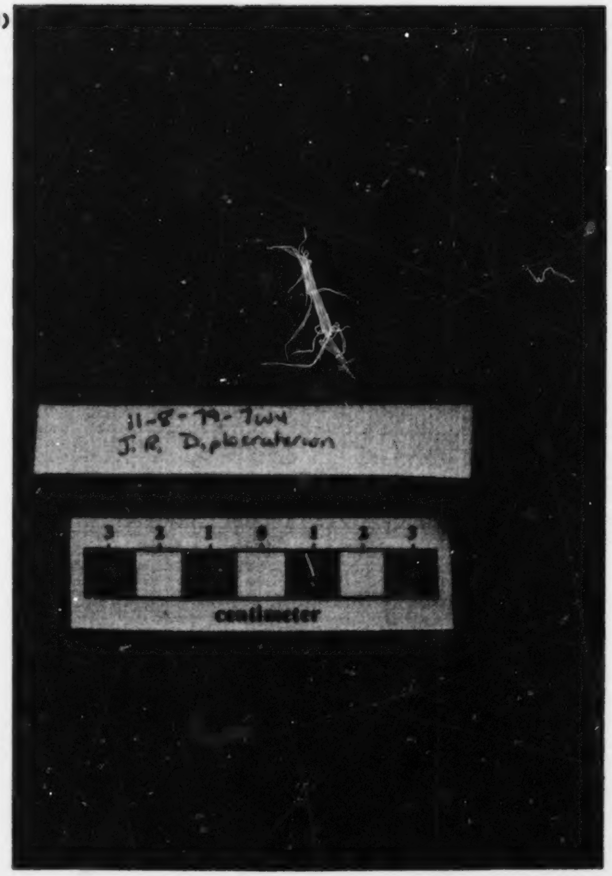

11-8-79-7W4
J.R. Diplocraterion
3 2 1 0 1 2 3
centimeter

Figure 25a) Planolites ~ 307.25 m; Well 11-8-79-7W4.Interdistributary Bay Facies.
Figure 25b) Diplocraterion? ~ 307.75 m; Well 11-8-79-7W4 .Interdistributary Bay Facies.

Figure 26a) Diplocraterion ˉ Highhill outcrop. Abandoned Esturine Channel Facies.
Figure 26b) Diplocraterion- Alternate View Highhill outcrop. Abandoned Esturine Channel Facies.

Depositional Environment

The McMurray Formation was deposited in a highly complex and diverse environment. In observing the cross-sections E-E', and F-F'(Figure 48-51), one can appreciate its variability. The sections are both datumed stratigraphically on the base of the lowermost marine unit of the Clearwater Formation, which is thought to be a regionally correlatable isochron. The depositional environment of the McMurray Formation has been divided into three genetic units based upon these environmental interpretations (Carrigy, 1959).

Lower McMurray Formation

The lower McMurray Formation was deposited by fluvial processes filling the topographic lows developed on the Paleozoic unconformity (Flach, 1984; Figure 19). It is characterized by fining upwards log signatures resulting from waning of depositional energy upwards indicative of fluvial facies as represented by the decreasing grain size and progressive trend to lower flow regime sedimentary structures. The presence of rhizoliths and a general lack of marine ichnofossils suggest that it is a continental deposit. This interpretation is consistent with other studies in the

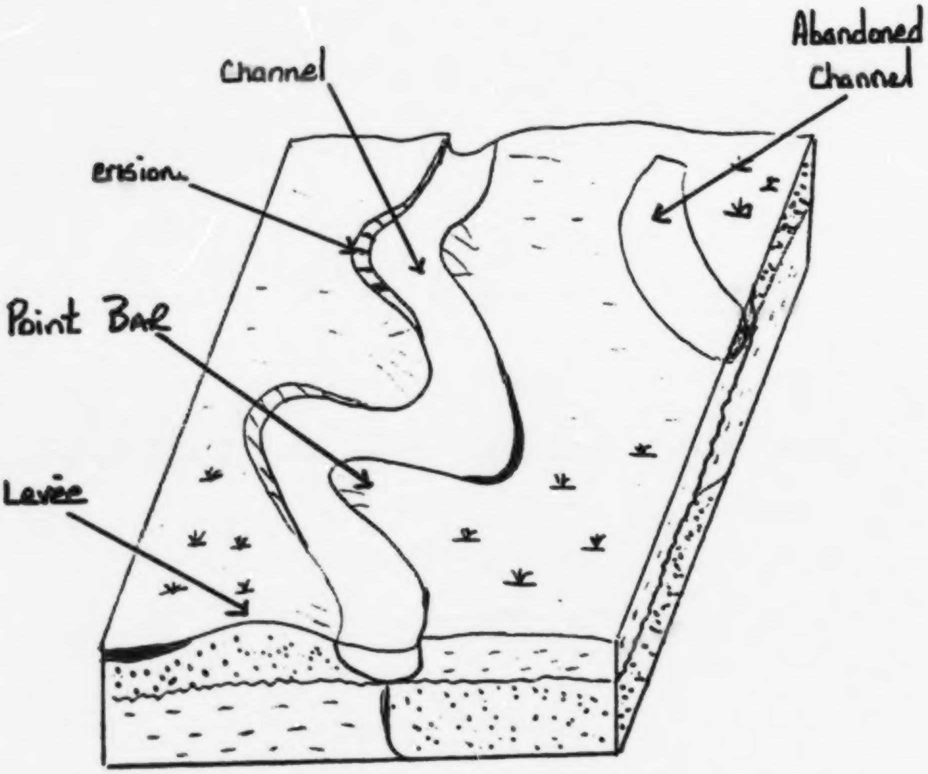

Abandoned Channel
Channel
erosion
Point Bar
Levée

Figure 27. Depositional Model of the Lower McMurray Formation.

same area (Carrigy, 1973; Flach, 1977; Flach and Mossop, 1985). These fluvial systems in the study area, are interpreted as having flowed to the northeast in the undisturbed zone, and to the southeast in the disturbed zone.

Middle McMurray Formation

Middle McMurray Formation time marked the onset of transgression of the Bullhead Sea. In response to this sea-level rise, an estuarine environment formed consisting of tidal flats and tidal channels, along with marine conditions to the northwest (Figures 28 and 29). Deposition within the study area kept pace with the rise throughout middle McMurray time. This environment was, like all McMurray Formation environments, highly variable and dynamic. The tidal flat deposits are generally massive muds and planar laminated silts and muds. Bioturbation is prevalent as are rhizoliths and siderite clasts. Rapid salinity changes controlled by flooding of fresh water and high evaporation rates are interpreted to have occured as evidenced by syneresis cracks (Wightman *et al.*, 1987). The high density and low diversity of the trace suite indicates a marginal marine brackish environment. Within the actual estuarine channel deposits, tidal influence is represented by

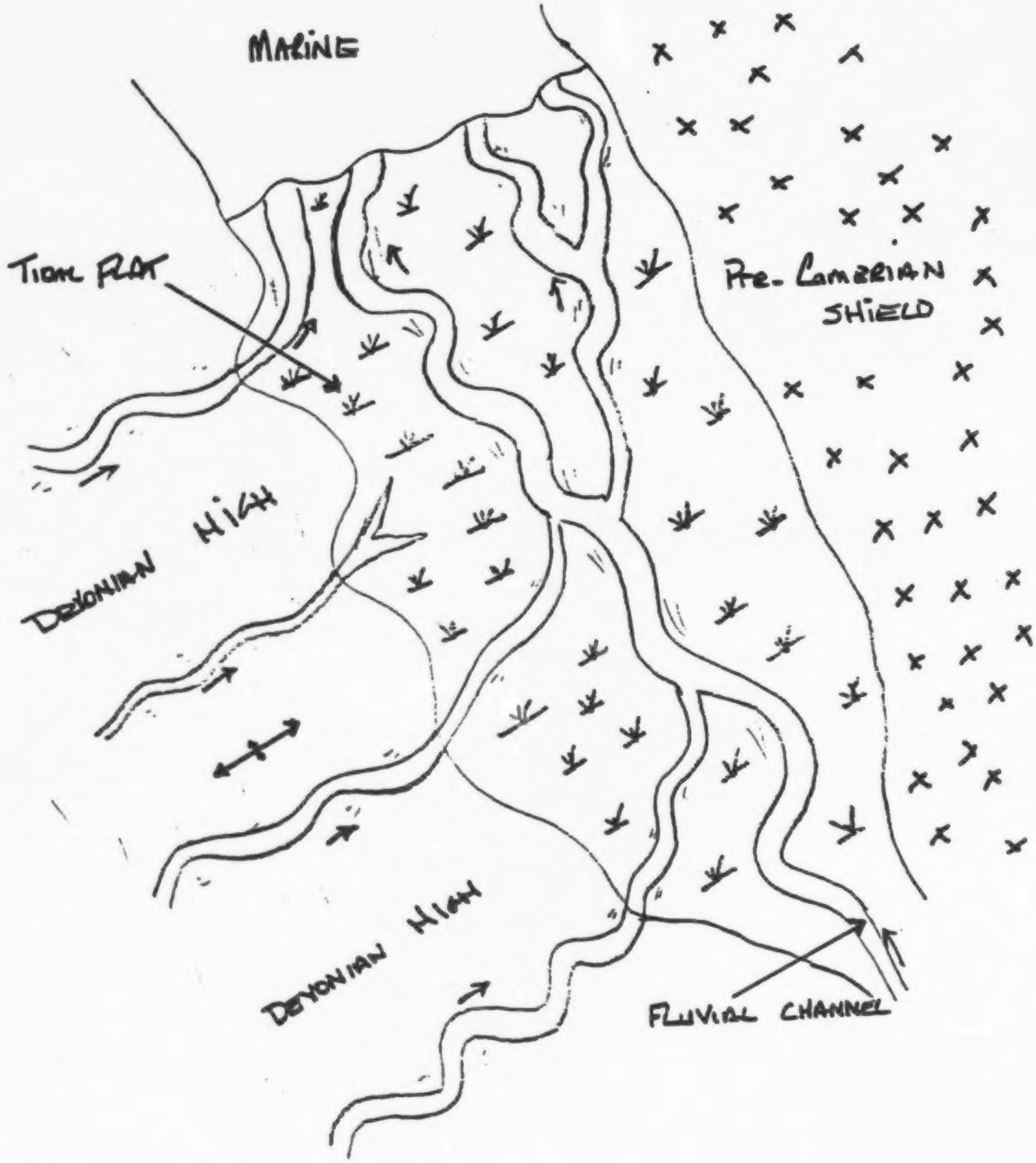

MARINE
TIDAL FLAT
PRE-CAMBRIAN SHIELD
DEVONIAN HIGH
DEVONIAN HIGH
FLUVIAL CHANNEL

Figure 28. Lower-Middle McMurray Formation; Tidal Flat.

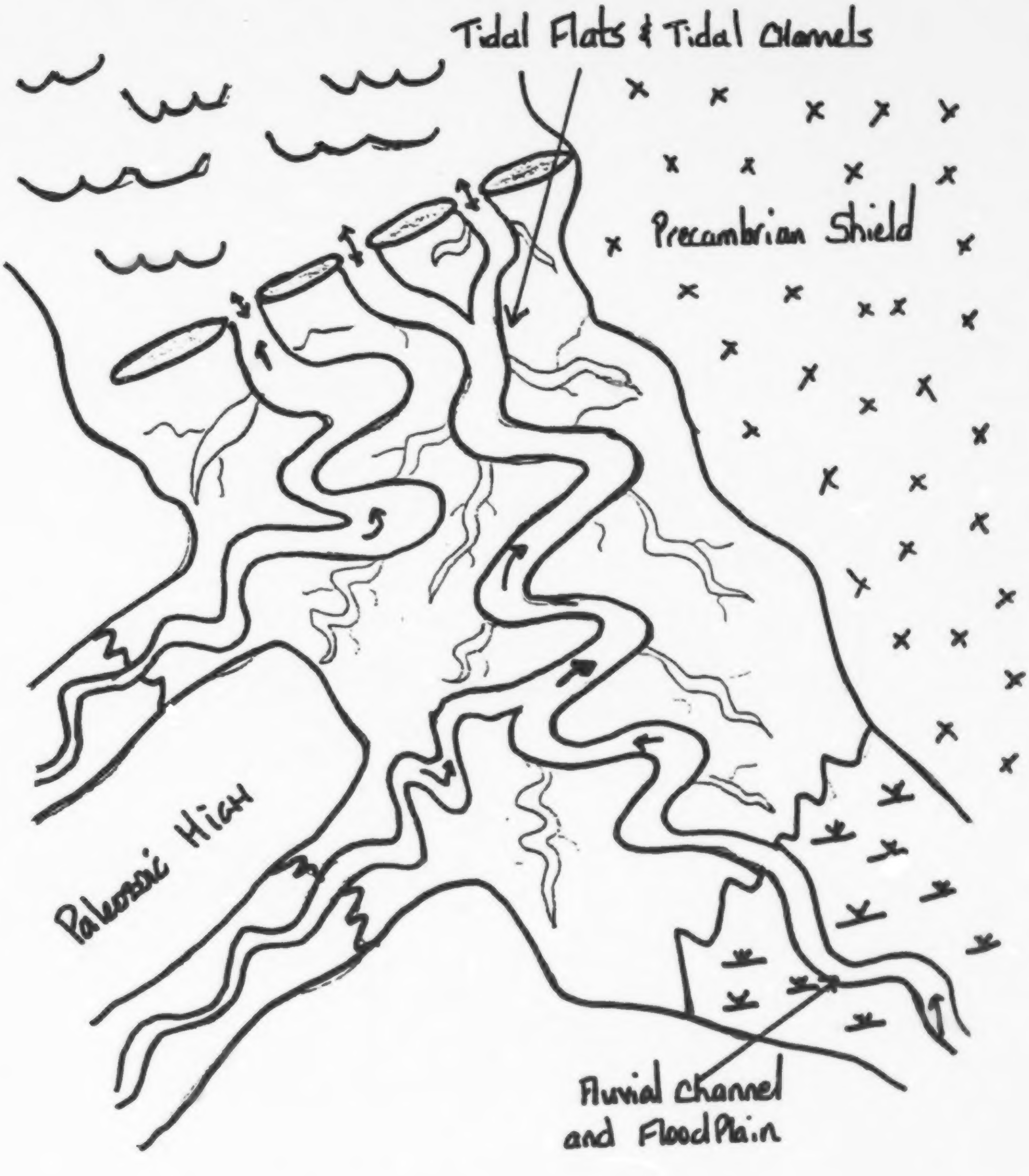

Tidal Flats & Tidal Channels
Precambrian Shield
Paleozoic High
Fluvial channel and Flood Plain

Figure 29. Depositional Model; Middle McMurray Formation.

tidal bundles and mud couplets, along with varing flow energy structures and reactivation surfaces. Within the Highhill outcrop, located on the Highhill river, a tributary of the Clearwater River approximately 60 miles east of Fort McMurray (Figures 31-34), this tidal relationship is easily seen. The estuarine channel facies commonly erodes the underlying fluvial and tidal flat deposits (Figure 30). The tidal influence is well documented by the tidal bundles and reactivation surfaces implying bi-directional flow (Pemberton *personal comm., 1991)*.

Upper McMurray Formation

Upper McMurray Formation sediments continue to conform to Walther's law; the environment of the Middle McMurray Formation has shifted to the northwest as the underlying sediments have filled in the estuarine environment. So while the estuarine environment still exists to the northwest, the adjacent distributary channel system and associated flood plain have moved from the southeast into the study area (Figure 35). The environment consists of distributary channels trending northwest-southeast, and associated flood plain deposits of crevasee splays and interdistributary bays. The interdistributary bays are characterized by rooting,

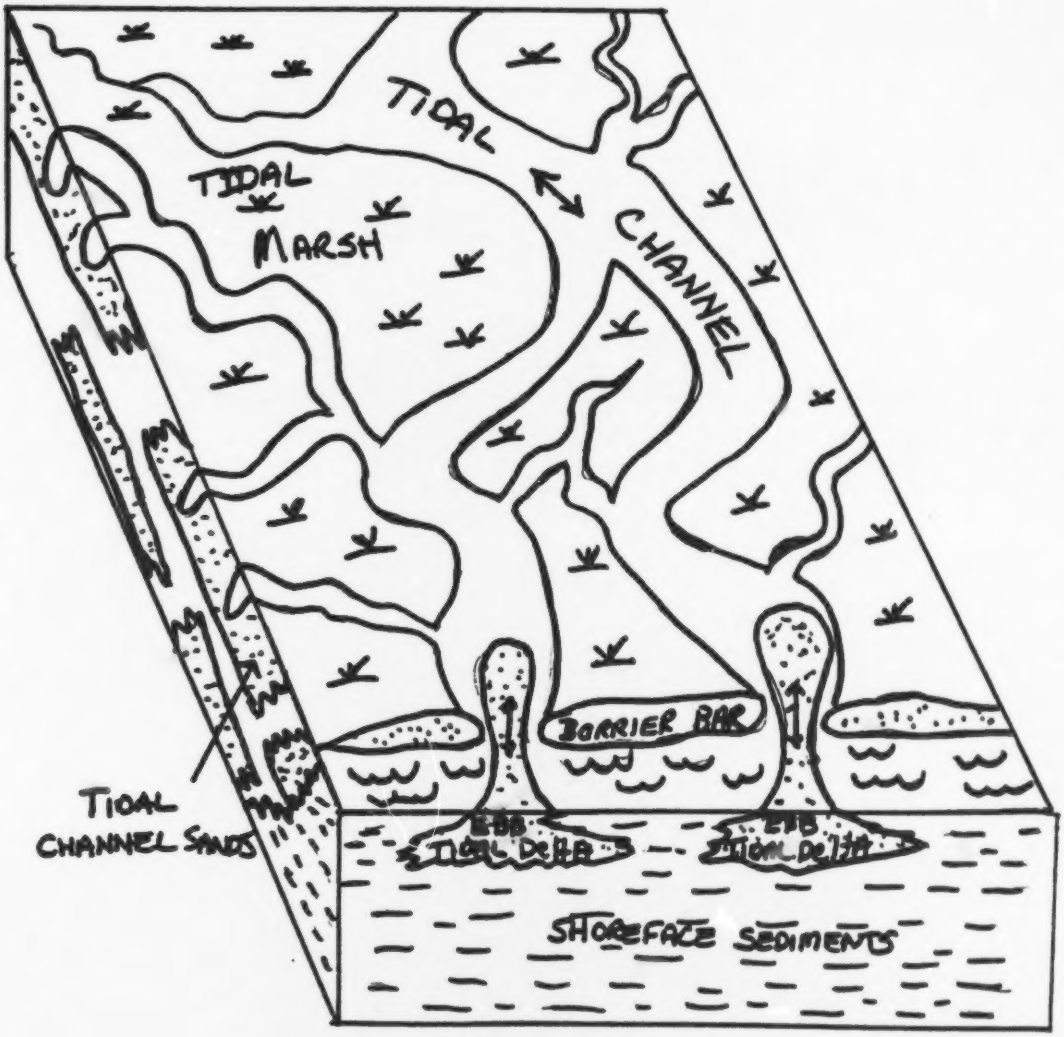

TIDAL
CHANNEL
TIDAL
MARSH
BARRIER BAR
TIDAL
CHANNEL SANDS
EBB
TIDAL Delta
EBB
TIDAL Delta
SHOREFACE SEDIMENTS

Figure 30. Tide Dominated Estuarine Environment.
(Modified after Hayes, 1976)

Figure 31a) Highhill Outcrop - On the Highhill River tributary of the Clearwater River; 65 mi. East of Fort McMurray.

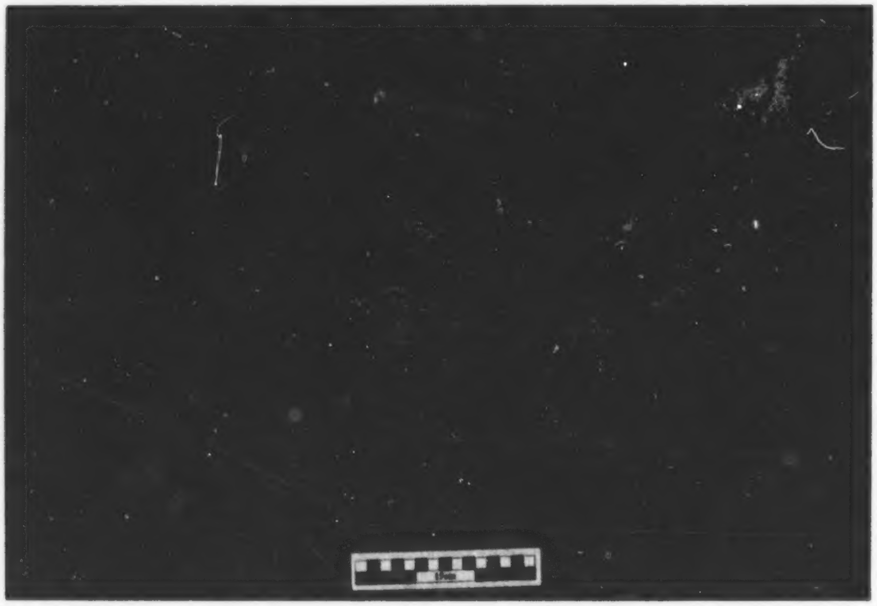


Figure 31b) Tidal bundles - Intermediate Estuarine Channel Fill.

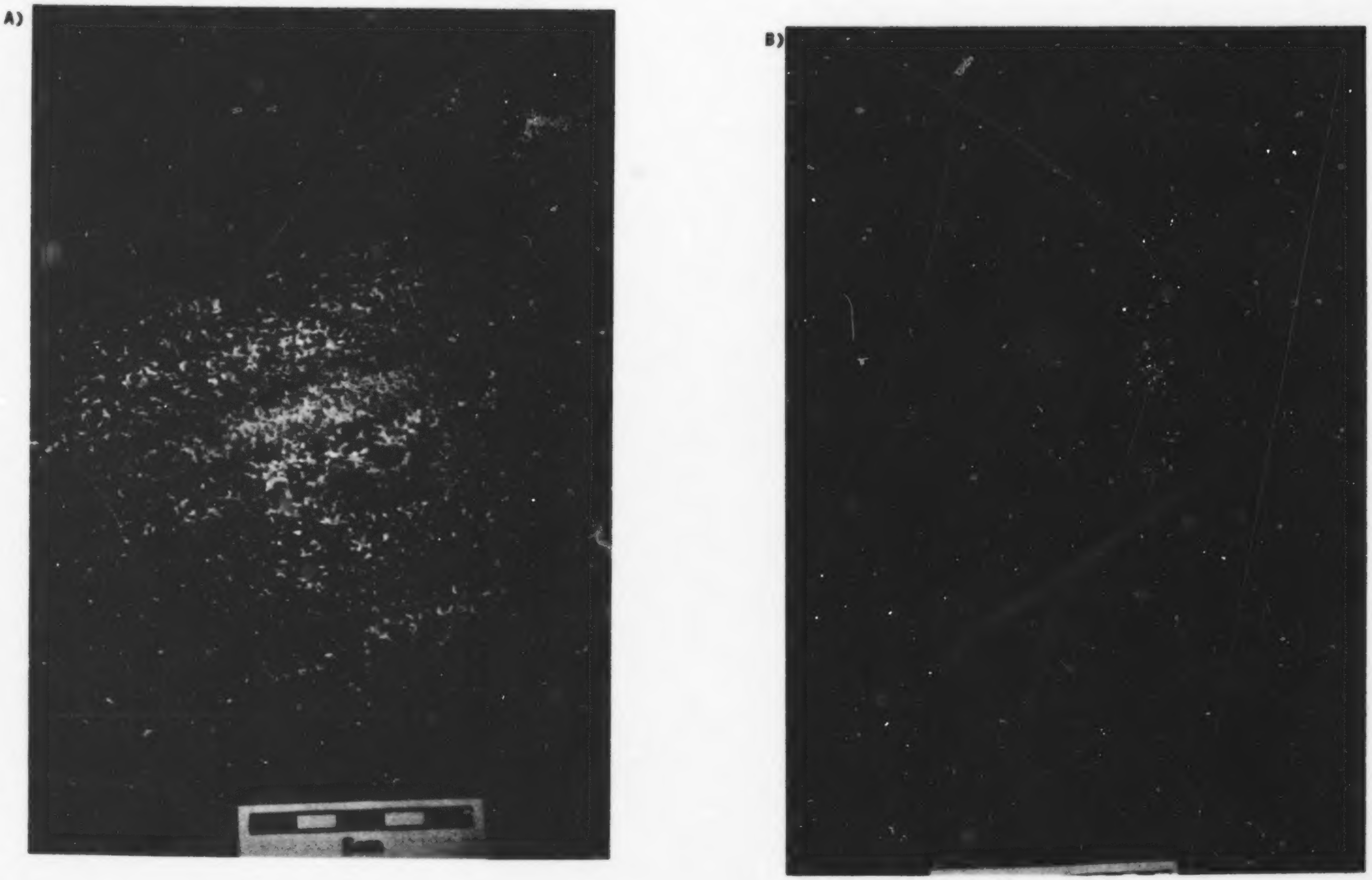


Figure 32a) Blow-up of tidal Bundles - Intermediate Estuarine Channel Fill.
Figure 32b) Tidal bundles, siderite clast - Intermediate Estuarine Channel Fill.

A)

B)

Figure 33a) Tidal Bundles - Intermediate Estuarine Channel Fill.
Figure 33b) Skolithos - tidal Bundles Intermediate Estuarine Channel Fill.

Figure 34a) Tidal bundles, siderite clasts, organics in toe-sets Upper Estuarine Channel Fill.

Figure 34b) Tidal bundles, siderite clasts, organics in toe-sets, mud lense. Upper Estuarine Channel Fill.

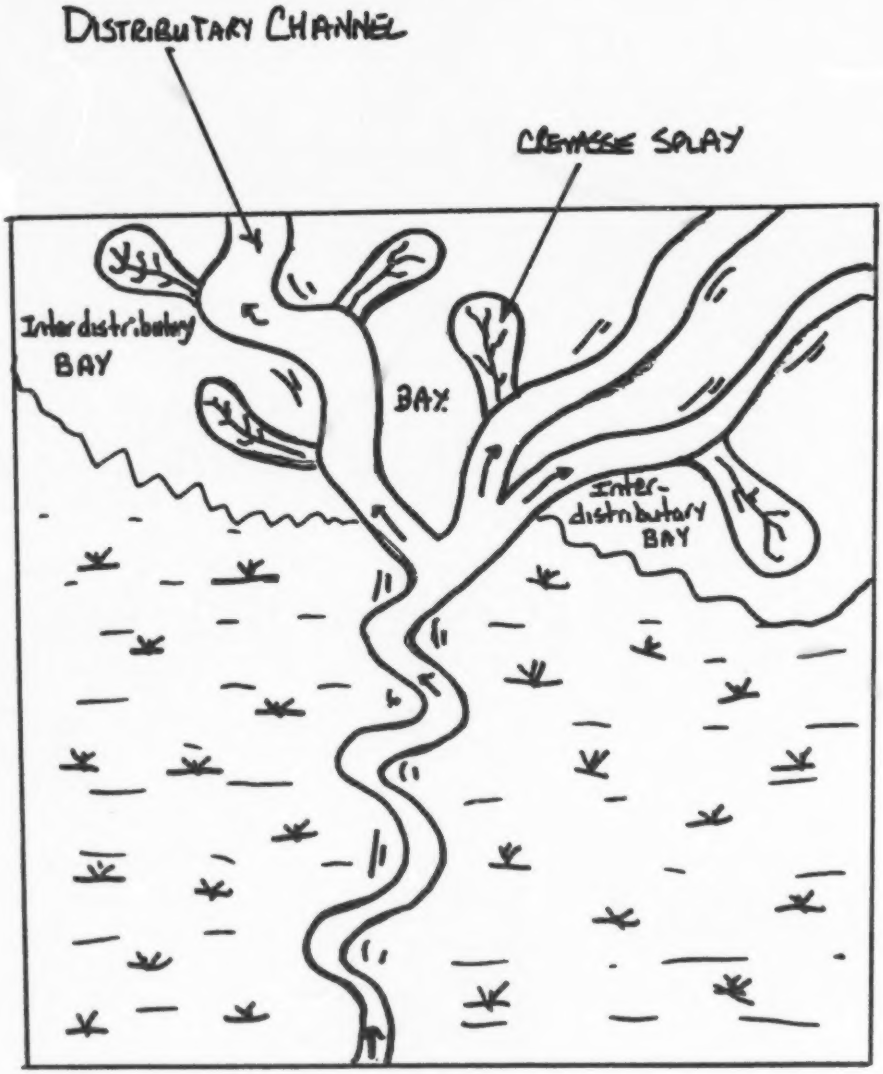

DISTRIBUTARY CHANNEL
CREVASSE SPLAY
Interdistributary
BAY
BAY
Inter-
distributary
BAY

Figure 35. Depositional Model; Upper McMurray Formation.

bioturbation, syneresis cracks, and siderite clasts within a generally massive mud or planar laminated silt and mud. Adjacent crevasse splays are generally less than 6 m thick; these coarsening upwards sequences are created by flow breaking out of the main channel and rapidly becoming unconfined (Figure 36). The distributary channels highlighting the Upper McMurray Formation drained northwesterly to the associated estuarine and associated marine environment. Distinguishing between the estuarine facies and distributary facies on logs is virtually impossible, although in core, the absence of tidal structures and reduced biogenic activity is quite definitive. The environment produces sand distributions equally as uncorrelatable as underlying McMurray Formation deposits leaving exploration largely to chance (Figure 63).

Clearwater Formation

The Clearwater Formation was deposited in response to the transgression of the Clearwater Sea. The lowermost Wabiskaw Member is a glauconitic sand interpreted to be a transgressive lag deposit formed as the study area was drowned by the rising sea. There are two main Clearwater sand deposits within the study area; the Clearwater 'A' and the Clearwater 'B' (Maher, 1989;

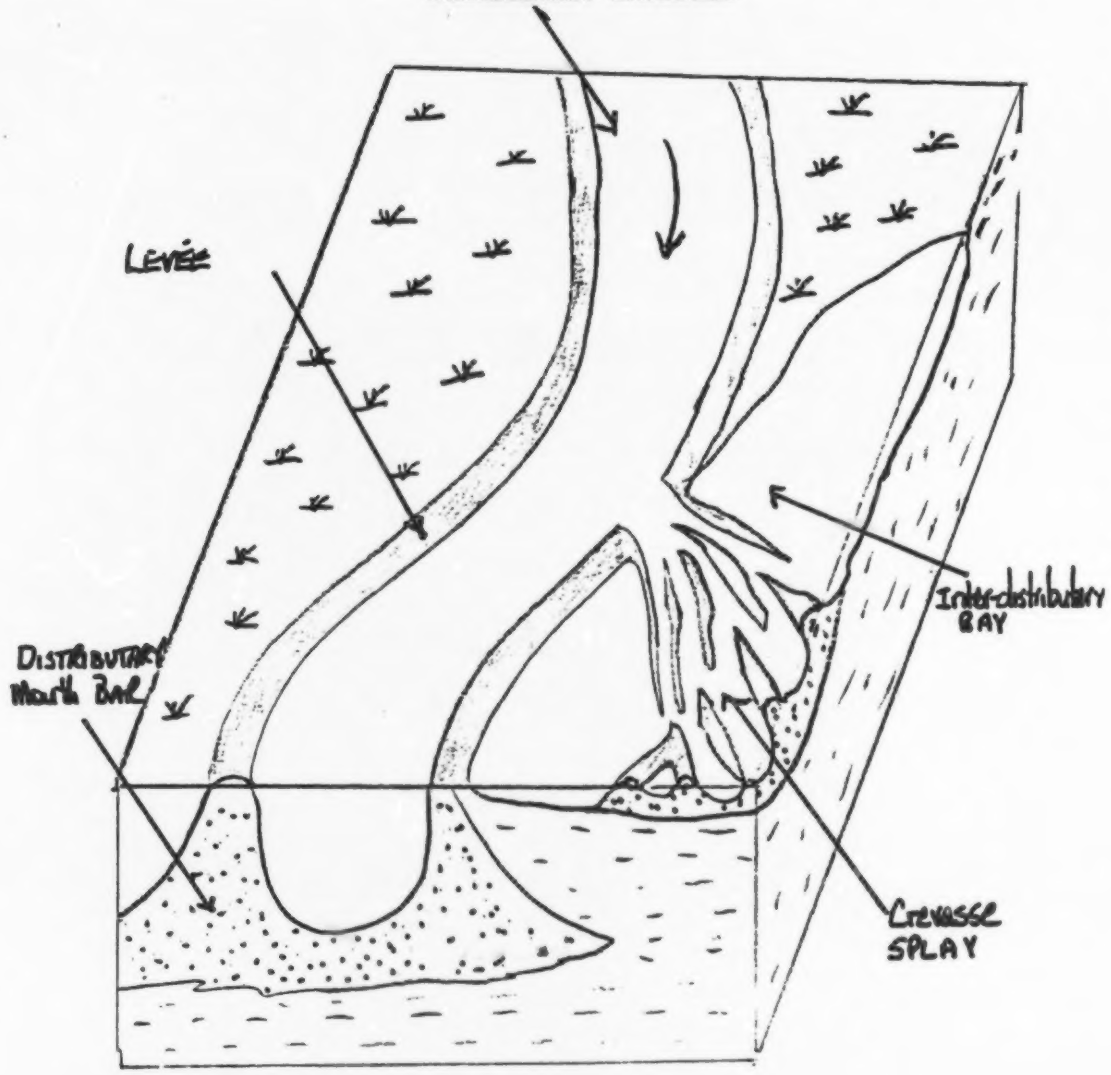

DISTRIBUTARY CHANNEL
LEVÉE
Inter-distributary BAY
DISTRIBUTARY Mouth BAR
Crevasse SPLAY

Figure 36. Tidal Flat Depositional Environent

Figure 59 and 60). The main Clearwater 'B' sand is found covering the majority of the southwest portion of the study area while the Clearwater 'A' sand covers only the northern edge of the area. Both sands were interpreted by Maher (1989), as nearshore barrier bar complexes which prograded northward (Figure 37). The sands are massive fining upwards sequences with no sedimentary or biogenic structures to help with interpretation. They are indeed continuous accross large areas, as shown in section D-D'(Figure 47), and are a substantial reservoir in the study area.

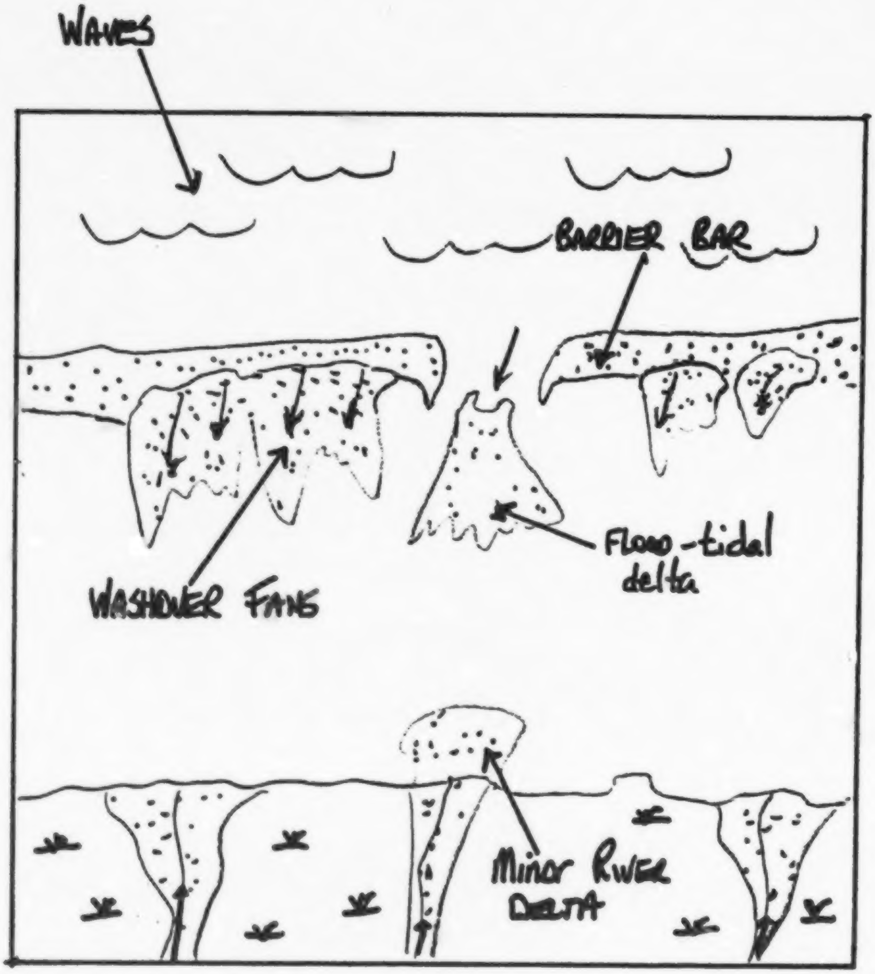

WAVES
BARRIER BAR
FLOOD-tidal delta
WASHOVER FANS
Minor RIVER DELTA

Figure 37. Clearwater Formation Depositional Model.
Wave-Dominated Micro-Tidal Barrier Bar.

Structural Regime

The structure in the study area is particularily complex because of the unique interaction of a variety of different forces. The study area has been divided into two structural regimes along a North - South trend located approximately in the middle of range 6W4. The eastern side is referred to as the disturbed, or collapse zone and the western side is termed the undisturbed zone. There are four main factors influencing structure in the area;

a)Erosion of the Pre-Cretaceous unconformity
b) Peace River Arch tectonics
c) Regional Dip
d) Salt Collapse

All of these factors contribute to the overall structural style in the study area with salt collapse being the dominant element in the disturbed zone. The other factors are more important in interpreting the structural style in the undisturbed zone. It is the interrelationship between these factors that complicates the interpretation. Each of the above elements will be discussed individually to provide information on the degree and manner of its influence, as well as the timing of the event.

SubCretaceous Unconformity Erosion

The remarkable topography of the Paleozoic unconformity surface is a result of the erosion by fluvial systems. The extensive relief of over 120 m on the unconformity surface can best be seen by examining Figure 57 (SubCretaceous Unconformity Map), along with cross sections C.2 (Figure 43) or C.3 (Figure 44) in the undisturbed zone. The evidence to support the predepositional existance of this structure lies in Figure 62 (McMurray Formation Isopach Map), showing the thickest portions of the McMurray Formation corresponding with the lows of the unconformity in the undisturbed zone.

This erosional system can be interpreted to have drained to the northeast leaving corresponding highs and lows parallel to flow. This trend is really only seen, and probably only remains, on the undisturbed side of the study area. The salt collapse events on the disturbed side have obscured any evidence of a southwestern-northeastern drainage trend, replacing them with northwestern-southeastern oriented collapse structures and further erosion along and within the subsequent structure. The relief shown by the northwestern-southeastern trending lows of the Devonian unconformity surface, (Figure 57), is evidence of drainage to the northwest. The erosional element in the disturbed zone is really quite trivial in relation to the collapse structures.

Influence of The Peace River Arch

The Peace River Arch, although hundreds of miles to the northwest, still influenced depositional conditions within the study area. Initially, it produced relief extending into the area which controlled drainage patterns. Secondly, its subsidence during the Laramide orogeny provided a slight thickening of the Mannville along the western edge of the study area (Christopher, 1980); (Figures 58, 61, 62). It should be noted that the underlying topography still greatly influenced sedimentation in the undisturbed Zone through Clearwater time.

Regional Dip

The characteristic southwesterly dip of the Western Canadian Sedimentary Basin is present in the undisturbed zone of the study area (Figure 43). This gently dipping structure existed until being interrupted by the salt collapse which, combined with the regional dip, formed the trapping mechanism for the Athabasca Oil Sands

Deposit. In addition to this, it provided the necessary conditions for migration of gas from the basin into the fields we find today (Moshier *et al.*, 1985).

Salt Collapse Structure

The dominant structural element in the study area is the salt collapse structure created by salt solution of the Middle Devonian Elk Point Group and subsequent collapse of the overlying Beaverhill Lake Group. (Hume, 1947; Carrigy, 1959; Stewart, 1963; Martin and Jamin, 1963; Flach, 1984; Keith *et al.*, 1987) This feature is considered to be the main contributing factor in trapping the entire Athabasca Oil Sands Deposit (Vigrass, 1966). The main collapse is found to run north - south along the boundary between ranges 6W4 and 7W4 through townships 79 and 78 before turning slightly to the southeast and leaving the study area at the boundary between ranges 5W4 and 6W4 (Figure 57). As previously mentioned, this structure divides the study area into a disturbed zone to the east, and an undisturbed zone to the west.

There is still some question as to the timing of the salt collapse. It is the nature of the event and lack of deep well control, combined with the other structural elements in the area that make a more precise

Figure 38. Seismic Section Across Salt-Collapse Zone.
(Paramount Resources, 1981)

llapse Zone.

assessment impossible. The collapse structure was initiated after Devonian time as evidenced by the seimic section (Figure 38), which shows the unconformity surface parallelling the immediately underlying reflector within the Devonian, probably the basal boundary of the Beaverhill Lake. This feature suggests that the structure at the unconformity surface cannot simply be erosional but that it must be attributed to some structural event. This indicates that salt collapse must have predated deposition of the McMurray Formation The general thickening of the entire McMurray Formation on the disturbed side also shows this (Figure 62). Moving up-section into the Clearwater Formation, the same structural pattern can be seen (Figure 52). Post-McMurray Formation deposition collapse can be seen by comparing the Clearwater Formation isopach map (Figure 58) and structure map (Figure 52). A general taming of relief has occured reducing maximum relief to 65 m, compared with over 120 m maximum relief on the Devonian unconformity surface, although Clearwater topography still mimics pre-McMurray Formation topography. It is proposed that the similarities in structure through time to the end of Clearwater deposition are a result of a combination of compaction of the thickest deposits within the paleo-lows, and continued salt collapse. To summarize, salt collapse had its greatest effect before and during deposition of the McMurray Formation, although it did continue to a lesser extent throughout Clearwater Time (Figures 52 and 54). A further review of the seismic section (Figure 38) shows this relationship of thickening deposits in the lows created by salt collapse, and the effect it had on the eventual structure in the area. The existence of post Clearwater deposition structure could be attributed to compaction, but in light of the shallow depth of the lower Mannville, continued salt collapse is the preferred explanation.

There are a number of explanations for the occurrence of the salt collapse. The main characteristics of each of the explanations are that the removal of Muskeg Formation salt resulted in collapse that has influenced subsequent deposition and hydrocarbon migration and trapping (Vigrass, 1966). The most prominant explanations are:

a) differential/partial dissolution,
b) preferential dissolution along fault planes/fracture patterns(McPhee,1991),
c) solution controlled by underlying Keg River reefs

It should be noted that the very limited number of wells penetrating the Muskeg Formation hinder the ability to provide the answer to what caused the salt collapse. The first possible explanation is that Muskeg Formation salt was removed east of the study area, and no salt was removed west of the collapse structure. The implication is that the groundwater dissolving the salt preferentially followed northwest-southeast trending paths resulting in the collapse which also trends in this direction. The second possibility is that recharge from the subcrop of the Muskeg to the northeast flowed southwest till it intercepted fault or fracture systems trending northwest-southeast resulting in flow along these vertical systems and subsequent collapse along these trends.(Don McPhee, *personal communication*,1991) The last explanation involves dissolution of the Muskeg Formation around underlying insoluble Winnepegosis Formation reefs. This appears to be the case in the seismic section (Figure 38) and a particularily good example is found in well 10-27-81-4W4 where all but 10 m of the Muskeg Formation has been removed from above a relatively thick Winnepegosis reef. The deposition of the Muskeg Formation was thickest in the lows surrounding the Keg River reefs and thus its removal would be greatest in these lows. This suggests that the Cretaceous structure could be indirectly controlled by the distribution of Keg River reefs. It could be more than coincidence that the northwest-southeast trend of the Cretaceous structure in the disturbed zone is the same as the probable trend of the Keg River reefs along the Devonian paleoshoreline.

Regardless of its cause, the removal of the Muskeg Fm. evaporites is responsible for the structure which is the dominant factor in the accumulation of hydrocarbons. The structure, created by the salt collapse, trends northwest-southeast, and represents an exploration strategy for the disturbed zone of the study area.

Conclusion

The four contributing elements of the structural regime in the study area are ranked in order of importance;

1) Salt Collapse,
2) Regional Dip,
3) Erosion of SubCretaceous Unconformity,
4) Subsidence of Peace River Arch,

Structure is the main trapping mechanism for hydrocarbons in the area and therefore a comprehensive understanding is necessary for exploration in the area. The two separate structural regimes should be mapped specifically with two theories in mind. The first is to map the undisturbed zone with highs and lows trending northeast-southwest; the second is to map the disturbed zone with trends at right angles to the undisturbed zone, along a northeast-southwest path.

Hydrocarbon Potential

There are really six main reservoir facies with economic potential within the Lower Mannville;

1) McMurray Formation
    a)Estuarine Channel
    b)Distributary Channels
    c)Crevasse Splays
    d)Fluvial deposits

2) Clearwater Formation
    a) Clearwater 'A' sand
    b) Clearwater 'B' sand

McMurray Formation

In the McMurray Formation, each of the interpreted channel, crevasse splay, and fluvial facies successions have excellent porosity and permeability. However, each succession is somewhat discontinuous. To further limit the reservoir facies, the lowermost fluvial facies can, for the most part be ignored as commercial hydrocarbons are generally not found that low within the section.

Two main types of hydrocarbons exist within the study area; heavy oil and natural gas. The Athabasca heavy oil deposit covers the western two thirds of the study area. As previously eluded to, regional dip combined with the major salt collapse have combined to create the structural trap responible for its accumulation. Moshier and Waples (1985), concluded that underlying sediments of the Devonian could not have generated the enormous volume of hydrocarbons found within this deposit. They speculated an up-dip migration of hydrocarbons from within the Deep Basin, which were then biodegraded in place. Due to the depth, the only means for extraction with current technology is in-situ recovery by steam injection, although researchers are investigating a large number of differing options in search of a step change in extraction costs. Possible future means of extraction include electric heating, in-situ combustion, horizontal drilling and extraction, and surfactant or polymer flooding. Estuarine and distributary channel sand facies successions will be the main economic alternatives for production of the heavy oil.

The McMurray Formation also holds potential for natural gas reserves within the study area. In todays economy, this is the only viable economic resource.

Natural gas has already undergone one major exploration and development phase, although further potential remains. Natural gas pay thicknesses can exceed 15 m, at pressures of over 300 psi. with porosity in excess of 30%. These make attractive shallow gas prospects for thrifty explorers. Trending from west to east across the study area, the gas is underlain by heavy oil, water and heavy oil, or water only (Figure 39). Whether the gas is associated with the migration of the heavy oil or is a secondary migration is yet to be determined. [Note that gas in the western portion of the study area lies above the heavy oil within continuous sands suggesting simultaneous migration of oil and gas or subsequent replacement of original gas caps.] Gas accumulation is found in structural highs (Figure 69), within Chard, Graham, Newby and Leismer gas fields; none of which are considered to be single continuous pools (Figure 50). The gas is further controlled by stratigraphy; the thickest gas pays are found in the channel sands (Figure 48) although economic proportions are also in the crevasse splay deposits of the Upper McMurray. Exploration plays for natural gas are aimed at finding the combination of structural highs coupled with distributary channel sands of the Upper McMurray Formation.

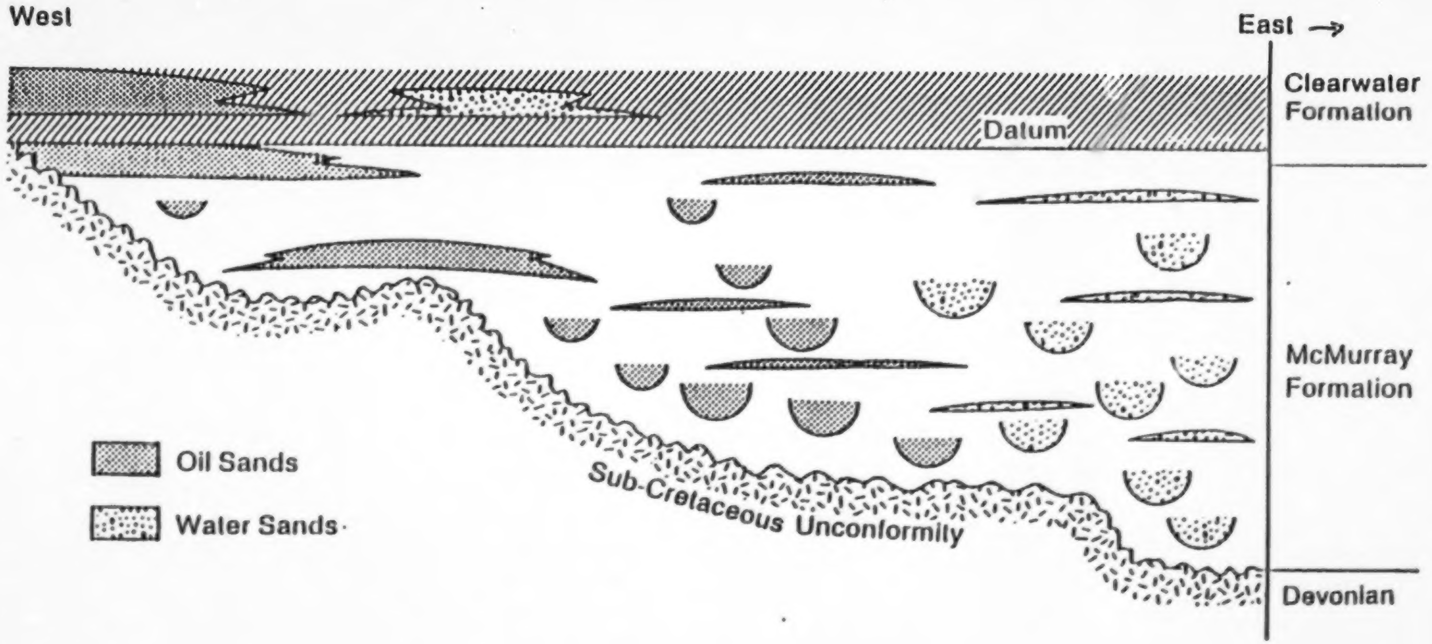

West
East →
Clearwater Formation
Datum
McMurray Formation
Devonian
Sub-Cretaceous Unconformity
▨ Oil Sands
▨ Water Sands

Figure 39. West-East trend from gas/H.O.- gas/H_2O/H.O.- gas/H_2O.
(modified after Wightman et al, 1987)

Clearwater Formation

The Clearwater Formation is devoid of any heavy oil potential but it does possess large reserves of natural gas. The Clearwater 'A' has small accumulations of natural gas created by very subtle structural closures (Figure 64). Although it is an excellent reservoir, it does not display a major up-dip structural closure. Clearwater 'C' stratigraphic levels show comparable gas reserves to the Clearwater 'A' (Figure 66), although the limiting factor controlling the Clearwater 'C' is lack of reservoir rock with any lateral extent. The lowermost Wabiskaw Member is also a reservoir within the study area, although it does not occur in sand thicknesses over 4 m. It is commonly associated with McMurray gas wells and can easily be produced in conjunction with the underlying McMurray Fm. gas.

The most economic Clearwater Formation play in the area is the Clearwater 'B' sand within the Leismer Field. Unfortunately the majority of petroleum and natural gas rights for the main Leismer Field have already been purchased. Some crown land is still availiable, possibly extending the field boundaries. The trapping mechanism is a combination of structure created by the main collapse across the area and stratigraphic closure of the bar complex with marine shales to the north (Figure 65) Significant gas volumes, (202 BCF), have been produced from the field between 1979 and 1989, with fourth quarter 1989 production exceeding 6 BCF.

To Summarize, The Upper McMurray Formation and the Clearwater 'B' Formation are the main exploration targets within the study area.

Economics

Two areas were chosen as potential development prospects based on the enclosed maps; structure, reservoir facies, and gas shows in surrounding wells were all used as criterion for these choices. These are merely two examples and by no means represent all the development potential in the study area.

The plays are best summarized in the reserve calculations and location maps in Figures 40 and 41. Approximate development costs per MCF of gas are provided, although the true economics of the play would need to evaluate the timing and cost of the capital investment. These general approximations are considered to clearly justify further study even at today's low natural gas prices.

Economic Potential : Leismer Field Extension

BHT = 23° C = 73° F = 533° Rankine

Q=(43,560*A*h*Ø)(T_a/T_s)[(P_s/14.4*Z_s)-P_a/14.4*Z_a)]

Where:

Q = ft^3 reserves @ S.T.P. (60° F, 14.4 psi.

43,560 = converts acres to ft^2

A = area in acres

h = gas pay(ft)

Ø = effective porosity

T_s= formation Temperature(° Rankine)(= 460° + °F)

P_s= formation pressure, psi.

P_a= abandonment pressure

Z_s= compressibility factor @ formation T and P.

Z_a= compressibility factor @ abandonment T and P

Assume : avg. gas pay Clearwater 'B' = 4 m;
Q/sec=43,560*632*13*.33*(520/533)*[(256/14.4*.97)-(100/14.4*.99)]
= 1.30 BCF/sec @ P_a=100 psi.
= 1.71 BCF/sec @ P_a= 50 psi.
= 2.00 BCF/sec @ P_a=14.4 psi.

13 Sections * 1.30 BCF/sec = 16.9 BCF
* 1.71 BCF/sec = 22.2 BCF
* 2.00 BCF/sec = 26.0 BCF

Assume : avg. gas pay McMurray Formation = 4 m
Q/sec=43,560*632*13*.33*(520/533)*[(301/14.4*.97)-(100/14.4*.99)]
= 1.68 BCF/sec @ P_a=100 psi.
= 2.08 BCF/sec @ P_a= 50 psi.
= 2.37 BCF/sec @ P_a=14.4 psi.

10 Sections * 1.68 BCF/sec = 16.8 BCF
* 2.08 BCF/sec = 20.8 BCF
* 2.37 BCF/sec = 23.7 BCF

Costs:
a) Seismic - 10 miles @ $7,000/mi. = $70,000
b) Land - @ $50/ha. = $294,400
c) Wells - 6 @ $125,000/well = $750,000
d) Gathering system - 12 mi. @ $150,000/mi. = $1,800,000
e) Compression - $3,000,000 for 10 MMCF/d
TOTAL = $5,914,400

Successful proposal finding cost incl. dev.= 5,914,400/43 BCF
= $.14 / MCF

All values approximated

Summary : Reserves = 33.7 BCF - 49.7 BCF
Costs: a) Seismic - 10 miles @ $7,000/mi. = $70,000
b) Land - 3328 ha. @ $50/ha.+ 2560 ha. @ $50/ha. = $294,400
c) Wells - 6 @ $125,000/well = $750,000
d) Gathering system - 12 mi. @ $150,000/mi. = $1,800,000
e) Compression - 3,000,000 for 10 MMCF/d
TOTAL = $5,914,400

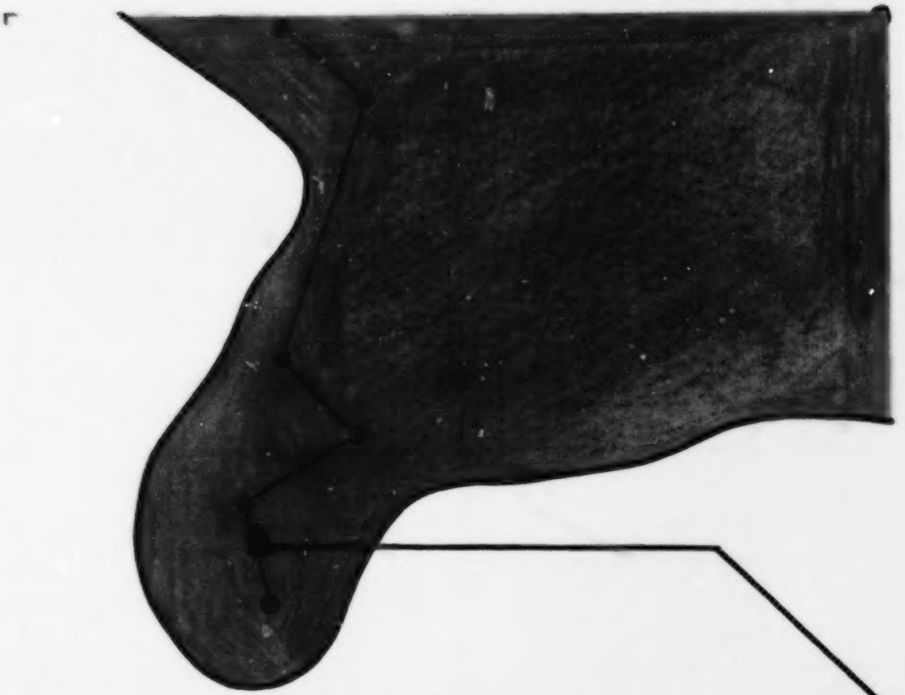
All values approximated

Summary : McM Fm. Reserves = 1.68 BCF/sec @ P_a=100 psi.
= 2.08 BCF/sec @ P_a= 50 psi.
= 2.37 BCF/sec @ P_a=14.4 psi.
10 Sections @ 1.68 BCF/sec = 16.8 BCF
@ 2.08 BCF/sec = 20.8 BCF
@ 2.37 BCF/sec = 23.7 BCF

● - proposed well location
▬ - Nova Pipeline
— - gathering system
■ - Nova meter station
▲ - proposed compressor station

Figure 40a) Leismer Field:McMurray Formation Development Outline

Leismer Field Extension : Clearwater 'B'

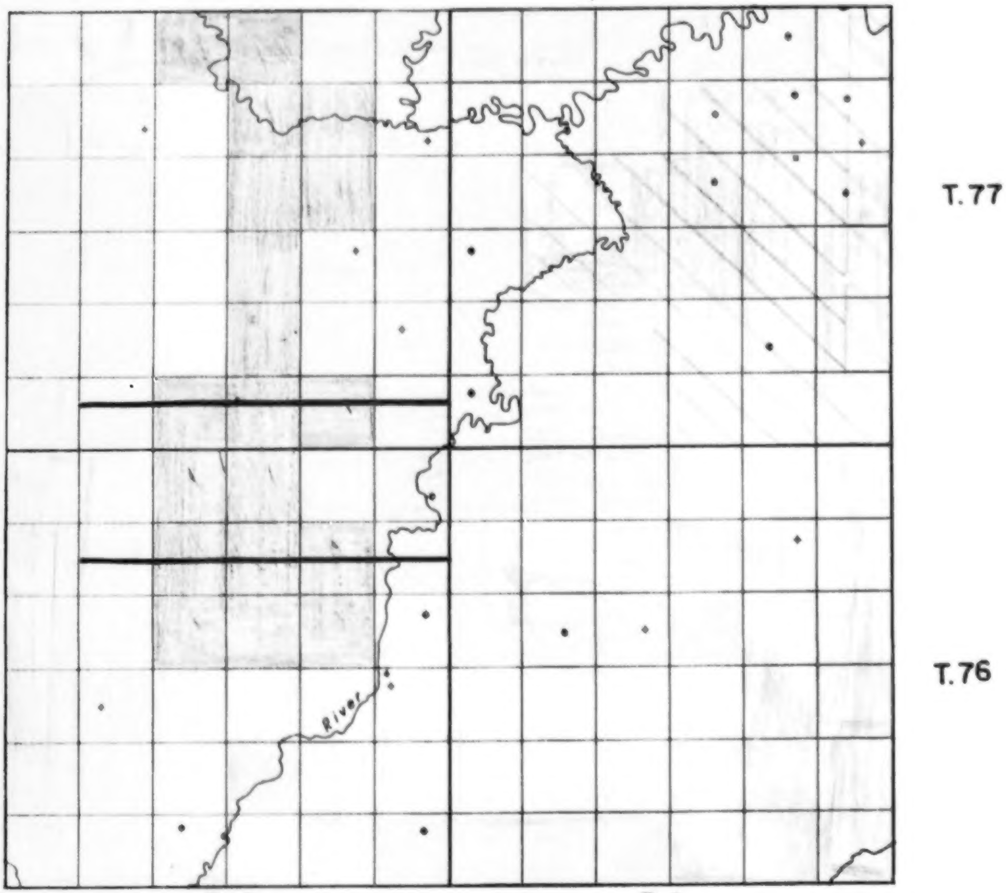


Summary : CLW 'B' Reserves = 1.30 BCF/sec @ P_a=100 psi.
= 1.71 BCF/sec @ P_a= 50 psi.
= 2.00 BCF/sec @ P_a=14.4 psi.
13 Sections @ 1.30 BCF/sec = 16.9 BCF
@ 1.71 BCF/sec = 22.2 BCF
@ 2.00 BCF/sec = 26.0 BCF

● - proposed well location
━ - Nova Pipeline
— - gathering system
■ - Nova meter station
▲ - proposed compressor station

igure 40b) Leismer Field:Clearwater Formation Development Outline

Leismer Field Extension


T.77
T.76
R.10
R.9
River

▨ - leased/licenced land
▨ - crown land
▨ - posted crown land
▬ - proposed seismic location

Figure 40c) Leismer Field Extension Base Map

Economic Potential : McMurray Formation - Graham Field Extension

BHT = 23° C = 73° F = 533° Rankine

$Q=(43,560*A*h*Ø)(T_a/T_s)[(P_s/14.4*Z_s)-P_a/14.4*Z_a)]$

Where:

Q = ft^3 reserves @ S.T.P. (60° F, 14.4 psi.

43,560 = converts acres to ft^2

A = area in acres

h = gas pay(ft)

Ø = effective porosity

T_s= formation Temperature(° Rankine)(= 460° + °F)

P_s= formation pressure, psi.

P_a= abandonment pressure

Z_s= compressibility factor @ formation T and P.

Z_a= compressibility factor @ abandonment T and P

Assume : avg. gas pay = 8 m;

Q/sec=43,560*632*26*.33*(520/533)*[(241/14.4*.97)-(100/14.4*.99)]

= 2.36 BCF/sec @ P_a=100 psi.

= 3.17 BCF/sec @ P_a= 50 psi.

= 3.75 BCF/sec @ P_a=14.4 psi.

17 Sections * 2.36 BCF/sec = 40.12 BCF

* 3.17 BCF/sec = 53.90 BCF

* 3.75 BCF/sec = 63.75 BCF

Costs:

a) Seismic - 12 miles @ $7,000/mi. = $84,000

b) Land - 4352 ha. @ $70/ha. = $304,640

c) Wells - 11 @ $125,000/well = $1,375,000

d) Gathering system - 14 mi. @ $150,000/mi. = $2,100,000

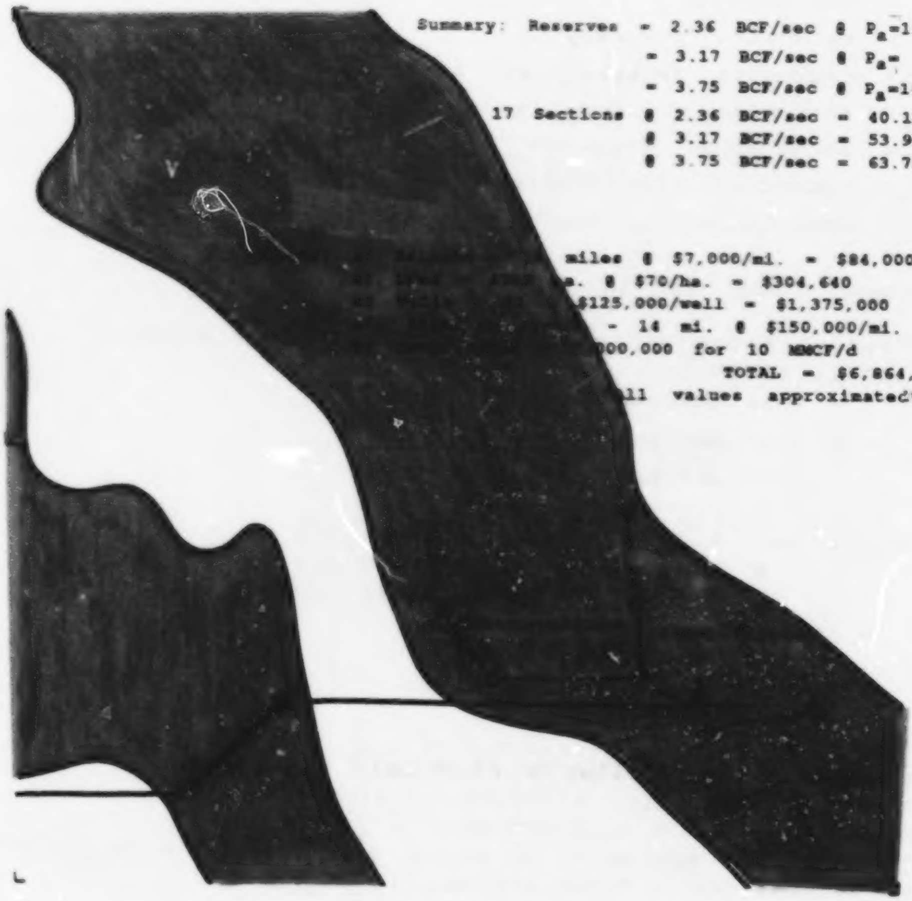
e) Compression - 3,000,000 for 10 MMCF/d

TOTAL = $6,864,040

Successful proposal finding cost incl. dev.= 6,864,040/54 BCF
= $.13 / MCF

All values approximated

Graham Field Extension:Development Outline



Summary: Reserves = 2.36 BCF/sec @ P_a=100 psi.
= 3.17 BCF/sec @ P_a= 50 psi.
= 3.75 BCF/sec @ P_a=14.4 psi.
17 Sections @ 2.36 BCF/sec = 40.12 BCF
@ 3.17 BCF/sec = 53.90 BCF
@ 3.75 BCF/sec = 63.75 BCF

miles @ $7,000/mi. = $84,000
a. @ $70/ha. = $304,640
$125,000/well = $1,375,000
- 14 mi. @ $150,000/mi. = $2,100,000
000,000 for 10 MMCF/d
TOTAL = $6,864,040
ll values approximated*

● - proposed well location
▬ - Nova Pipeline
— - gathering system
■ - Nova meter station
▲ - proposed compressor station

Figure 41a) Graham Field Extension Development Outline

Graham Field Extension

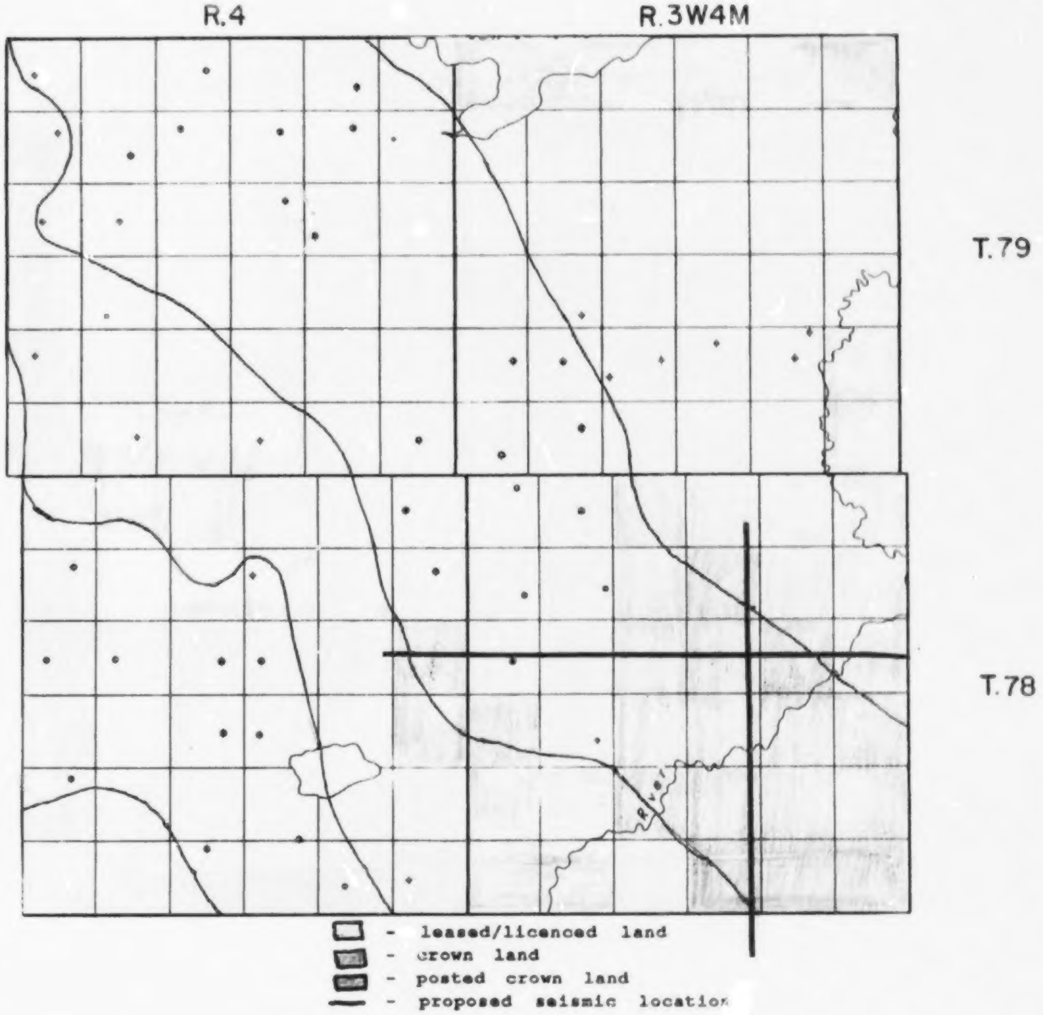

R.4
R.3W4M
T.79
T.78
River
☐ - leased/licenced land
▨ - crown land
■ - posted crown land
— - proposed seismic location

Figure 41 b) Graham Field Extension base map

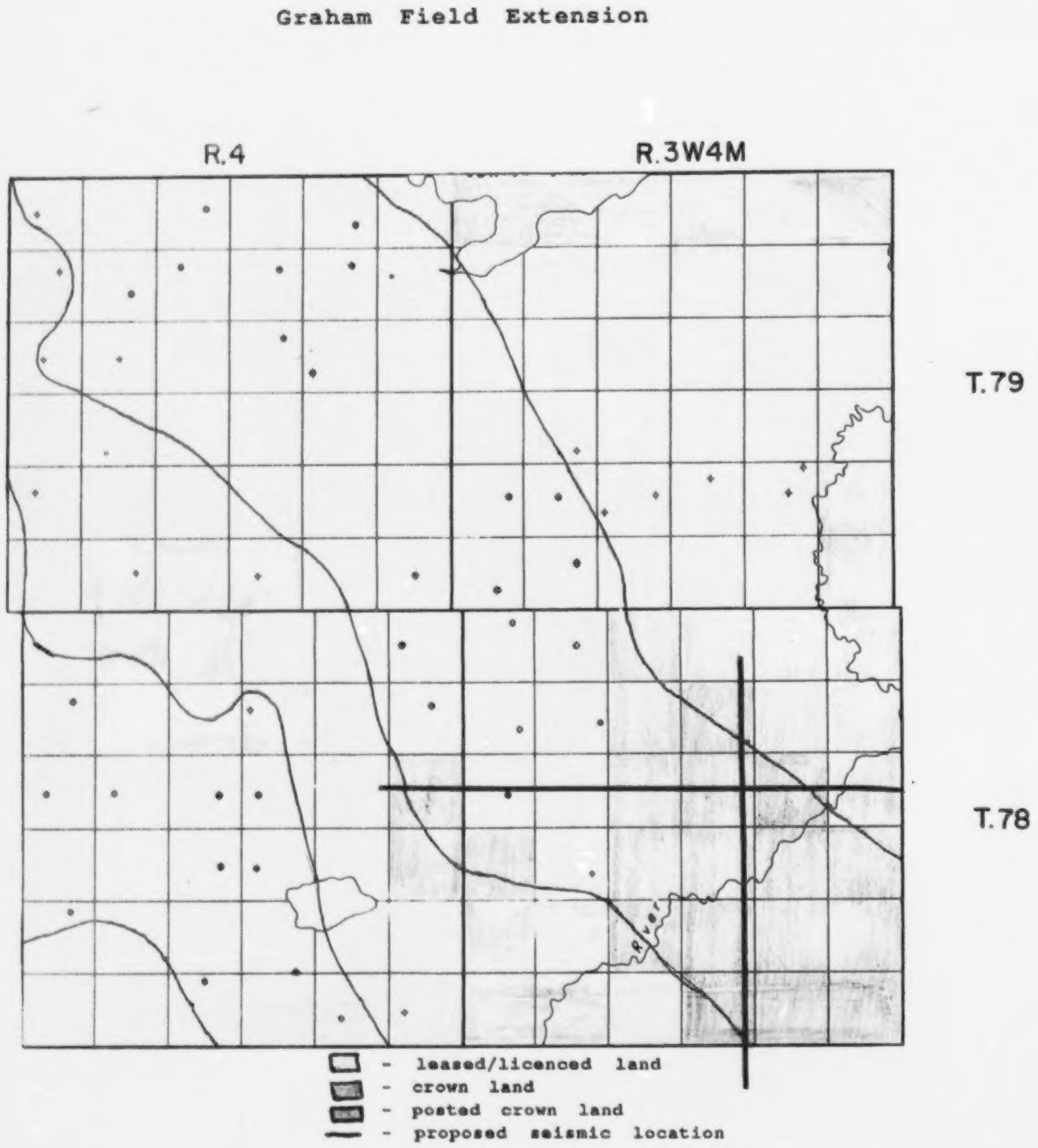

Graham Field Extension
R.4
R.3W4M
T.79
T.78
River
- leased/licenced land
- crown land
- posted crown land
- proposed seismic location

Figure 41 b) Graham Field Extension base map

Summary

1) The McMurray Formation is the depositional response to the transgression of the Bullhead sea into a well defined paleovalley informally termed the Athabasca Channel.

2) The Cleawater Formation was deposited during transgression of the Clearwater Sea.

3) McMurray Formation strata in the study area are subdivided into lower, middle, and upper units corresponding to deposition within fluvial, estuarine, and distributary environments respectively.

4) Clearwater Formation Strata in the study area are comprised of the lowermost Wabiskaw Member transgressive lag, and a succession of northward prograding nearshore bar complexes referred to as Clearwater 'A'- 'C' sands from top to bottom.

5) Structure is controlled by erosion of the Paleozoic Unconformity, regional dip, Peace River Arch subsidence, and salt collapse.

6) These structural elements have created linear highs and lows trending northeast-southwest in the

undisturbed zone; and linear highs and lows trending nothwest-southeast in the disturbed zone. These two structural zones are divided by the major north-south trending salt collapse.

7) Heavy oil and natural gas are of economic importance within the study area. A trend from gas-heavy oil contacts, to gas-water-heavy oil cotacts, to gas-water contacts is found to exist from west to east accross the study area. Present economic conditions leave only the natural gas as a development target.

8) Highest Potential Reservoir rocks with economic potential in the study area are the McMurray Formation channels and the Clearwater 'B' sand.

9) Gas distribution is controlled by the linear trending highs and lows in the McMurray Formation; the major salt collapse coupled with facies distribution is responsible for heavy oil and the main Leismer Field gas accumulation.

10) Economics for two possible play configuations are presented with reserves of 40-64 BCF to be developed for the gross consideration of $6,864,040 at Graham, or $.14/MCF if successful; and 34-50 BCF to be developed for $5,914,400 gross, or $.13/MCF if successful at Leismer.

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APPENDIX A

Core Descriptions

MCMURRAY CORES

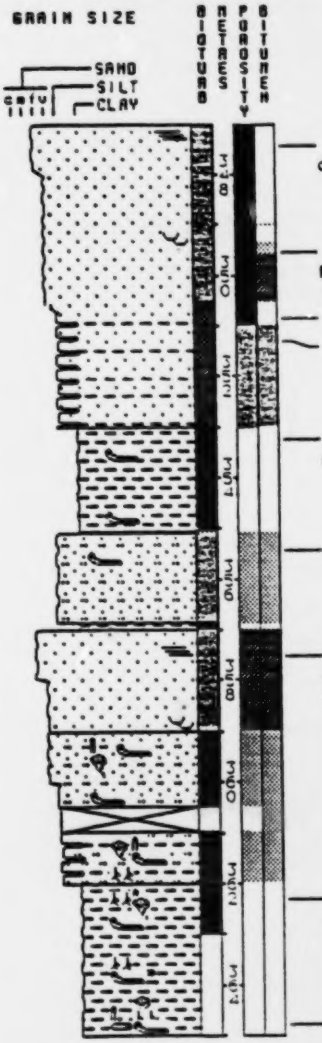
1. 10-8-79-8W4
2. 10-14-76-7W4
3. 10-23-76-8W4
4. 11-1-77-8W4
5. 11-2-77-8W8
6. 11-8-79-8W4
7. 11-8-79-6W4
8. 11-8-79-7W4
9. 3-1-77-5W4
10. 5-16-79-5W4
11. 6-11-78-7W4
12. 8-17-78-7W4
13. 9-1-80-8W4

CLEARWATER CORES

14. 11-34-77-8W4
15. 6-22-77-8W4
16. 6-9-77-8W4

PEH PCEJ LEISMER OU 10-8-79-8

10-8-79-8w4



vfg Ss, lightly stained, burrowed, waning flow energy downwards, planar bedding at top.

H.O. / gas contact @ 349.3 m; x-bedded Ss. fining down, flow wanes down.

intb. Ss/ silt/sh. fines down, bioturbation increases.

lt. gy. mud, burrowing- planolite, few coarse silts are stained;

burrowed silty sand, stained, massive, S.S.D.

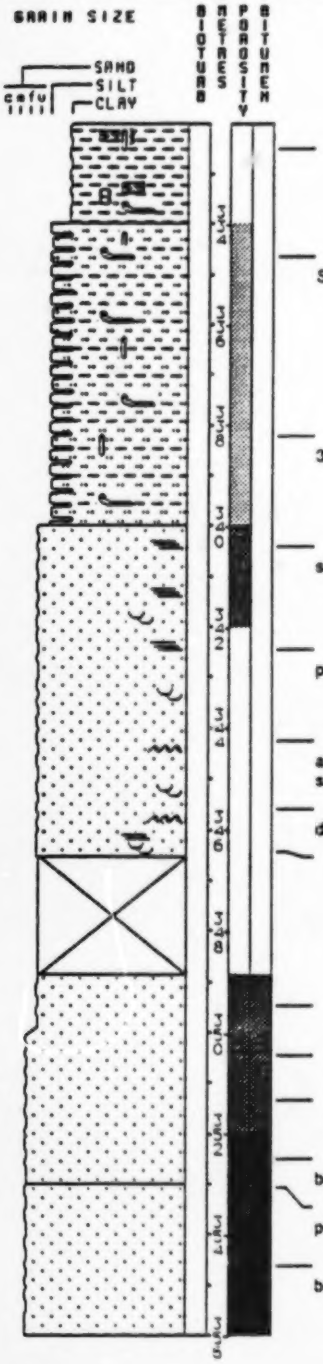
sand content increase up; burrowing in mud intense, skolithos, planolites, asterosoma, , incresed flow energy upwards.

ly gy mud, bioturbated, root structures, planolites, asterosoma, skolithos

mud, rooting, planolites, skolithos, asterosoma, paleophycus.

Home Leismer 10-14 MN THR

10-14-76-7w4



lt gy mud, organics, planolites, skolithos, brachiopod shell,

intb silt/sh, deeper water than above?, sid clasts, plan. Skol, increasing shale/sand ration upwards.

intb silt/sh, lt gy sh, sid clast, plan, skol, ssd, sid layer @ 339.7 m

vfg ss., increasing organics upwards, some x-bedded sands, mostly planar bedded,

lt gy ss, vfg, massive-planar bedded, detrital on bedding planes

lt gy ss., vfg, organics and shale clasts on bedding planes and in troughs of x-beds, contact @ 344.5 m, ly gy salt/pepper to lt brn ss.

vfg ss, fluctuating current sm ripples-planar beds, clay drapes

transition from oil stain to gas sand, lt stain, below 346.3 m.

fg-vfg ss, masive, oil saturated

fg-vfg ss., massive , oil saturated, few rip up clasts, sh.

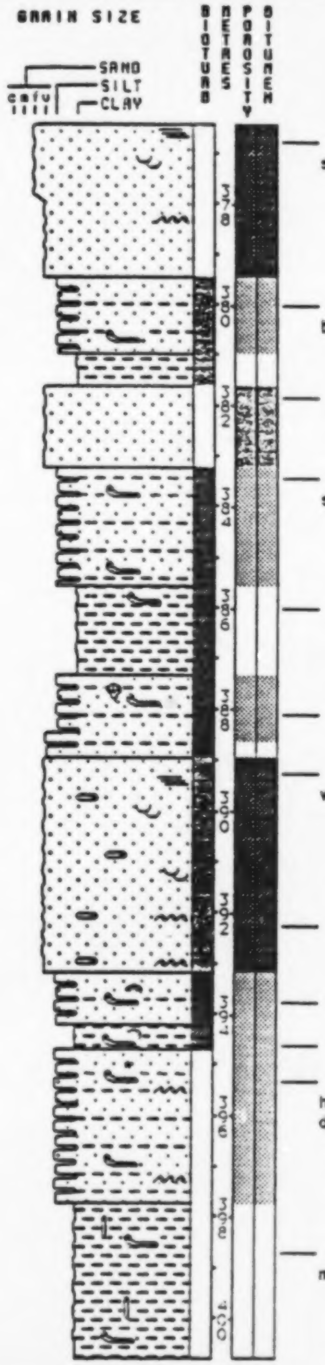
fg-vfg ss. ssd, oil stain,

fg ss., massive, some prograding ripple sets near top of box, s cm high,

fg ss, massive, clay drapes 8 cm thiock, ssd, few rip ups, possible planar bedding.

fg ss, some thinner clay drapes downward, ssd, some burrows in sh, oil saturated .

Home HB Leismer
10-23-76-8w4


GRAIN SIZE
SAND
SILT
CLAY
c m f vf
BIOTURB
METRES
POROSITY
BITUMEN
378
380
382
384
386
388
390
392
394
396
398
400

Ss, oil stained, coarsening up, flow strength increases up. some planolites in mud near base of unit.

Intb sand/mud, mud content increased down, mud burrowed

vfg ss. well sorted, 90% sand, massive

Intb. Ss. - sh., increasing sand up, burrowing intense, stained coarser units, planolites

Lt gy mud, massive, no stain!, burrowing

intb sand/mud, burrowed, stained, plan. asterosoma, ?

vfg ss., oil stained, lg scale x-beds, planar beds at top, waning current down, paleophycus

vfg ss, small scale ripples, paleophycus,

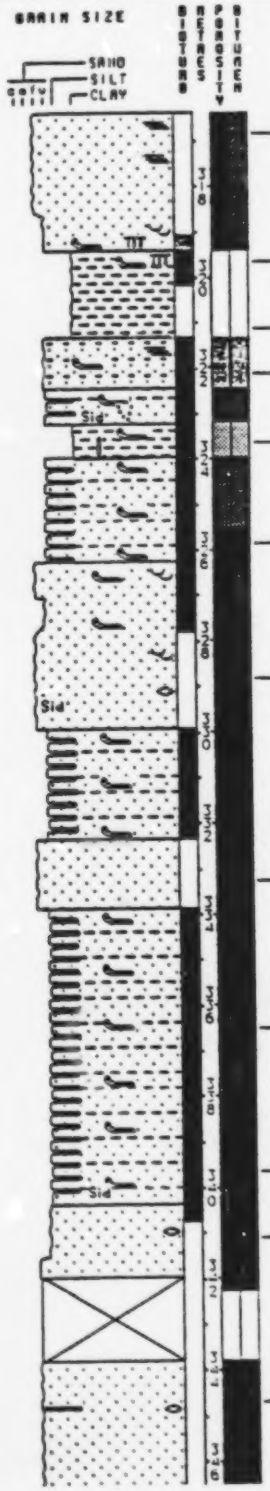
intb ss/sh, increasing sand up, sand stained.

ly gy mud, ssd, burrowed.

intb sand/sh., increasing sand up, ripples in sand, some higher flow regime beds, sand opil stained, some clay drapes,

lt gy mud, some planolites, no stain in burrows, mud massive.

HOME HB LEISMER 11-1
11-01-077-08w4



Ss. fg, coarsening up from vfg, oil stained but not heavily, planer beds near top, lower flow regime down, syneresis cracks and planolites in muds of lower unit.

mud becoming burrowed, planolites, some staining of burrows although light, syneresis cracks.

mud, lt gy, massive, little burrowing.

shaly sand, lighter staining, bioturbated, x-beds near top, large slump deposit,

mud, bioturbated, planolites, diplocraterion, asterosoma, sid clasts,

intb ss-sh, fining up, increasing mud up, planolites in mud, oil stained sand and traces, some sid clasts.

Ss, fg, fining up again, shale clasts, sid clasts, massive,

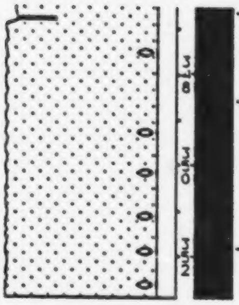
Ss, fg, oil stained, vague trough x-beds, rip up clasts at base;

intb sand-mud, general continued fining up, planolites, planar laminations, oil staining of sand. Mud component increasing up.

intb sand-mud, mud is ly gy, planolites burrows, oil stained traces; Ss is vfg, massive (some trough x-beds seen, individual sands avg. 5-10 cm thick, mud 2-5 cm thick.

Ss, fg-vfg, continued fining up, oil stained, massive, mud clasts

Ss, fg, still fining-up, oil stained, massive appearance, mud clast coated by coal.



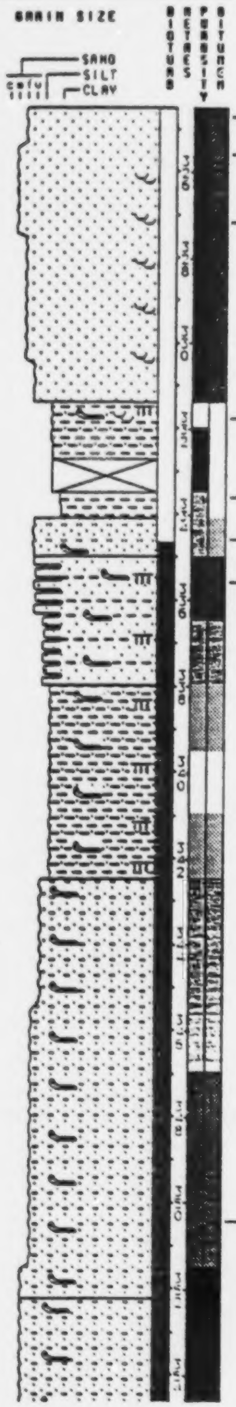
Sa, fg, oil stained, massive appearance, coal clasts, general fining up of sands.

Sa, mg, oil stained, massive, same facies as below, 1 cm. thick clay later seen, staining still too heavy for structures to be visible.

Sa, mg, oil saturated, massive appearance, rip up clasts of mud.

HOME LEISMER 11-2

11-02-077-08w4



Ss., lt gy-green, fg, massive and some burrowing

Ss, fg, light br. slight oil stain increasing down. massive

Ss. coarsening up, good staining, large scale cross beds.

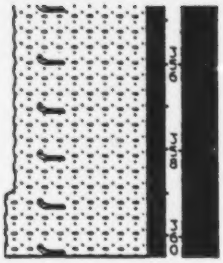
intb shale-sand, planolites, syneresis cracks, large cross beds in sand

lt gy mud, planar laminated

lt br. ss. bioturbated, v. little staining

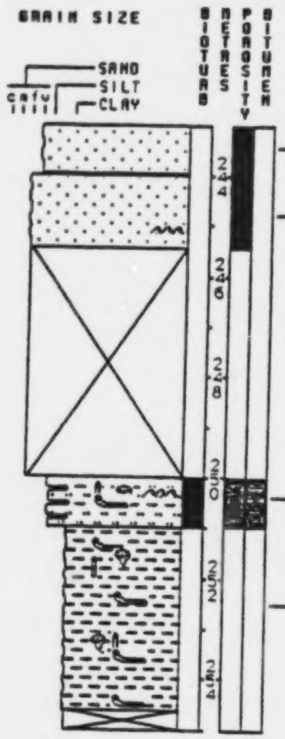
intb ss-mud, increasing sand upwards, sand oil stained, bioturbated, planolites and possible diplocraterion, syneresis cracks and s-s-d in muds.

This is a large facies unit consisting of intb sand and silt units with an overall fining up trend represented by the sands becoming finer and less thick while the muds become more dominant upwards. Planolites is very abundant in the fine units, and all the sands and the burrows are oil stained. The units are lacking structure except for rare cross-beds.



PEH PCEJ Chard OU 11-8-79-6

11-8-79-6w4


GRAIN SIZE
SAND
SILT
CLAY
c m f v
BIOTURB
METRES
POROSITY
BITUMEN
244
246
248
250
252
254

vfg gy/green Ss. massive, definitely Wabiskaw sand

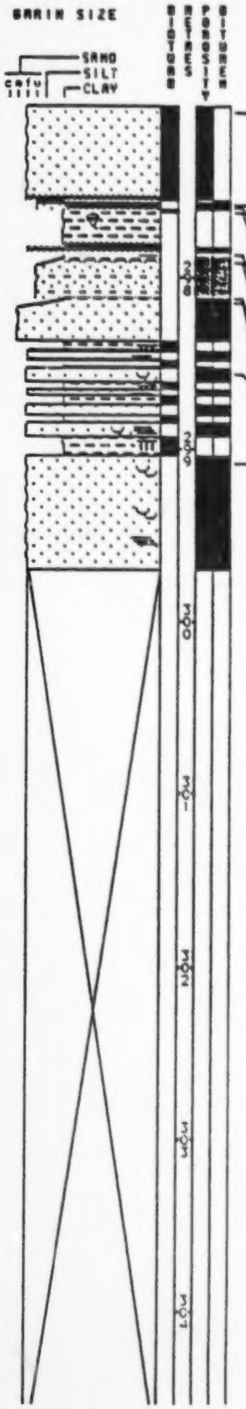
sharp Wab/MCM contact
lt. brn fg ss. clay drapes, massive sand with some ripple structures, gas sand.

intb. silt/sh. burrowed shale, planolites, asterosoma, planar laminated silts, skolithos, ripple structures increasing shale content down, coarsening upwards

mud, gradational contact, planolites, skolithos, asterosoma, coarsening upwards,

PEH PCEJ Leismer 11-8

11-8-79-7w4


GRAIN SIZE
SAND
SILT
CLAY
c
m
f
v
BIOTURB
METRES
POROSITY
BITUMEN
298
299
300
301
302
303
304

intbd silt / sand.

intbd. fg ss. - mud; grad fining up, burrowing.

fg ss. planar beds, low angle x-beds.

mud, lt gy. syneresis cracks, astrosoma?(brachish water - est.)

Flame Structures / dewatering S-S-D

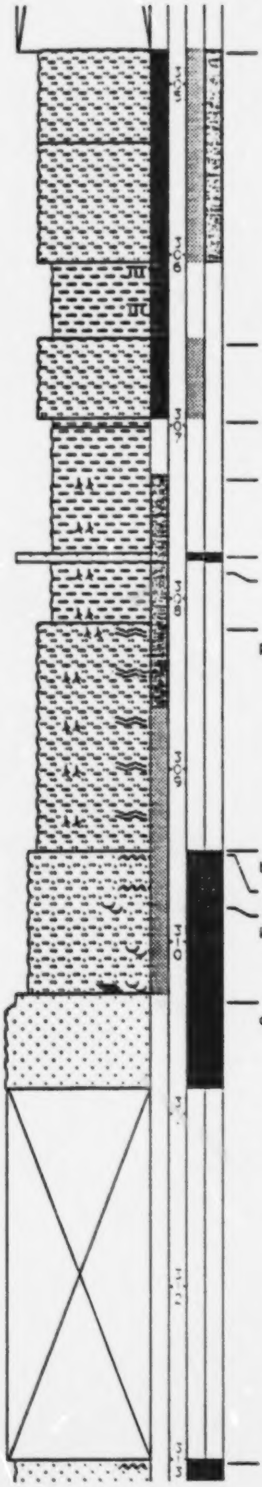
intbd planar laminated mud - fg Ss. Sands oil stained.

thin mud streak, gradational boundary. S-S-D.

fg Ss. oil staining, massive

intb - fg Ss / ly gy mud - planar bedding, trough x-beds, oil staining in Ss. - planolites and syneresis cracks in mud.

fg Ss., oil stained, grades upwards from planar beds to trough x-beds. This implies waning of current upwards.



mud / silt / sand - oil staining of sand, planolites

lt gy mud, heavily burrowed, Diplocraterion? planolites?

lt gy mud

ly gy mud, plant rooting structures - coal filled.

Ss. possibly storm deposited, oil stained, S-S-D

lt gy mud, rooting structures filled with coal

intbd silt-mud, wavy and flaser bedding, little burrowing planolites, plant rooting infilled with coal present.

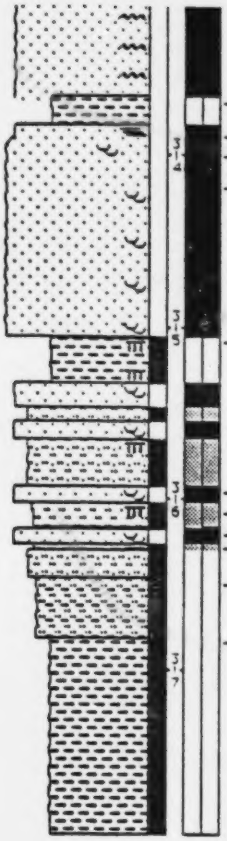
SIDERITE CLAST, Hi Fe+2 content - possible result of burrowingcausing high iron concentration to accumulate.

intbd silt / sand - prograding ripples

trough x-beds grading into small ripples.sand content increasing, thus porosity and oil staining are increasing also.

mg Ss, massive, oil stained, continued increase in sand content, oil saturation, and porosity.

fg Ss, small scale ripples, prograding



mud / silt, scoured top, gradational bottom

fg Ss, planer bedding, oil stained

trough x-beds

mg Ss, larger scale trough x-beds

lt gy mud, syneresis cracks

fg ss, trough x-beds,

mud / silt, syneresis cracks, planolites

fg ss, trough x-beds,

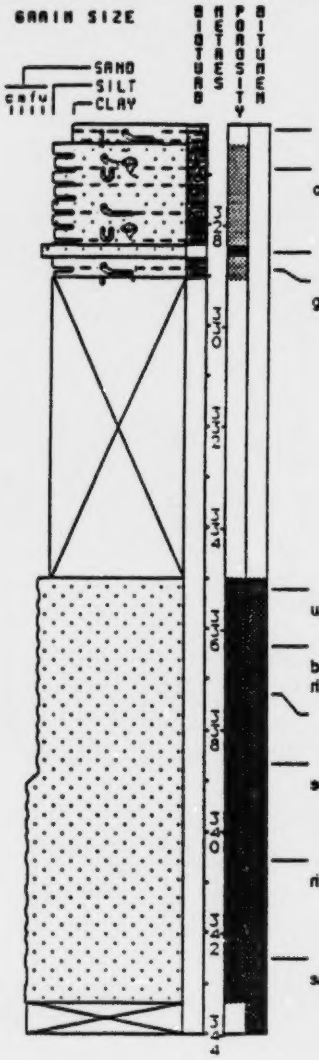
mud / silt, syneresis cracks, planolites, sand fraction increasing upwards

silt, sand increases up, planolites

lt gy mud, burrowing, planolites

CWWE Leismer 3-1-77-5

3-1-77-5w4


GRAIN SIZE
SAND
SILT
CLAY
c m f v
BIOTURB
METRES
POROSITY
BITUMEN
328
330
332
334
336
338
340
342
344

shale, fissile, thin silt lenses, burrowing limited

sand/silt, massive sands, SSD, planolites, syneresis cracks, arenicolites, skolithos, burrowing increases upwards

ly brn ss, well sorted, massive

thin laminated intb. mud/silt/sand, no stain, SSD, gradational packages fine up.

vfg Ss. , massive, clay drape frequency increases upwards, oil saturated

vfg ss. massive, mud drapes inclued, point bar/hummocky?
rip-up clasts.

vfg ss. clay drapes, no rip-up clasts, oil saturated, massive

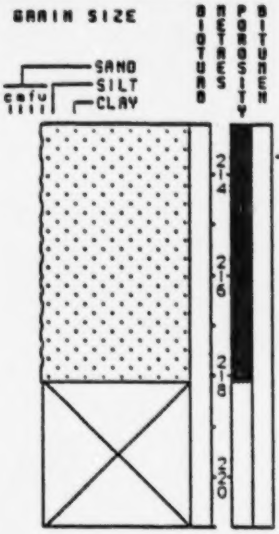
fg-vfg Ss. massive, random rip-ups, oil saturated, well sorted

fg-vfg Ss. massive, oil saturated, clay drapes absent, clay rip up clasts, oil saturated.

fg-vfg Ss. inclined clay drapes, thin- avg. 3 mm. massive sands, bitumen saturated, rip up clasts above clay drapes.

ICGA CHARD 5-16

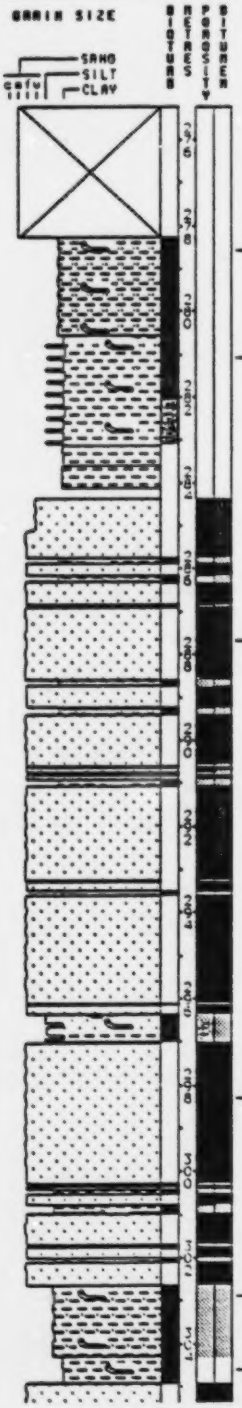
5-16-79-5w4


GRAIN SIZE
SAND
SILT
CLAY
c m f v
BIOTURB
METRES
POROSITY
BITUMEN
214
216
218
220

vfg Ss., lt gy. massive, similar to channell @ 10-14-76-7W4 near top; no organics, no burrowing, clean gas sand throughout.; poor core, washed too much?

HOME LEISMER 6-11

06-11-78-07w4


GRAIN SIZE
SAND
SILT
CLAY
cmfv
BIOTURB
METRES
POROSITY
BITUMEN

Silty shale, slight oil stain, planolites, bioturbated

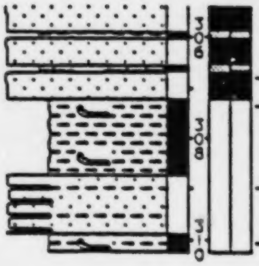
Intb silt-shale, increasing silt content upwards, silt is slt oil stain, planolites and possible Asterosoma.

Ss, fg, shale breaks, oil staining, shale breaks show planolites, bioturbated

Ss, fg, shale breaks, oil staining, shale breaks show planolites, bioturbated

Ss, fg, shale breaks, planolites in shale, bioturbated shales.

Thinly laminated mud, bioturbated, planolites+, traces replaced with coarser material



Ss, fg, shale breaks, shales show planolites

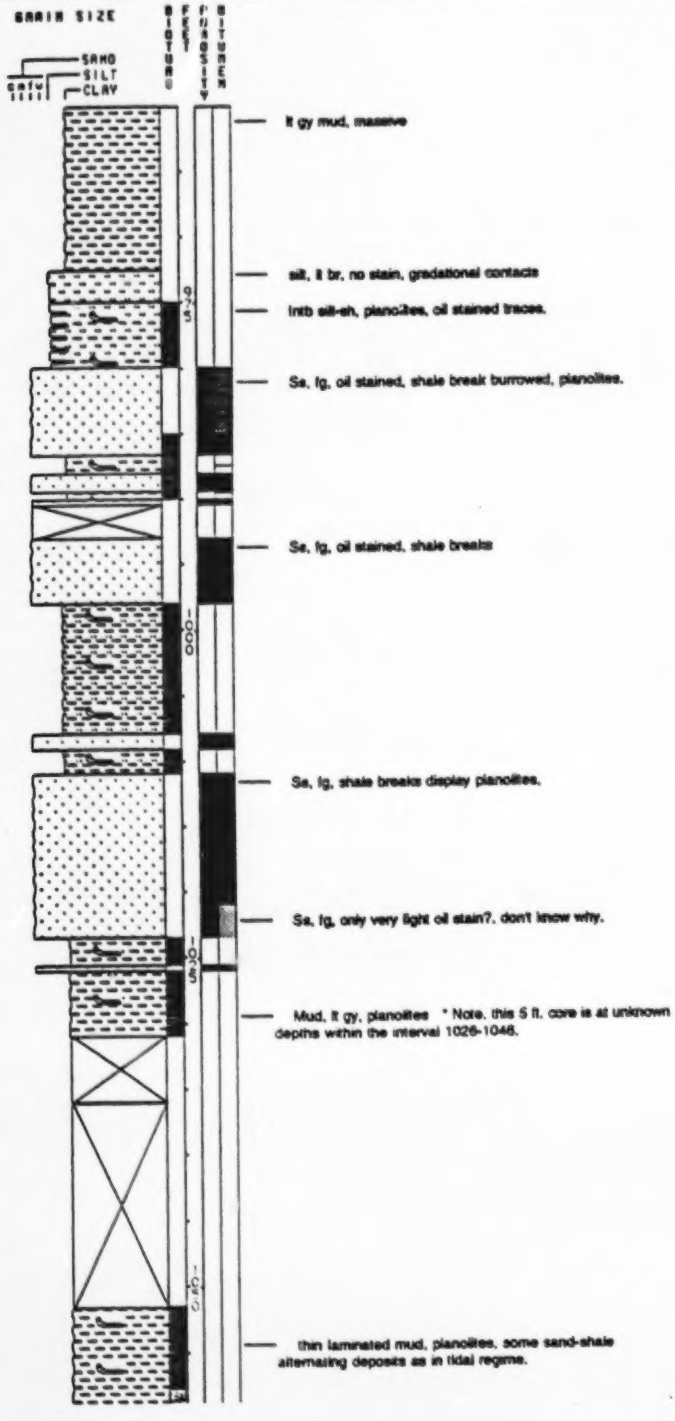
Thinly laminated mud, bioturbated, planolites+, traces replaced with coarser material

Ss, fg, shale breaks, shales show planolites, oil stained

Thinly laminated mud, bioturbated, planolites+, traces replaced with coarser material

R O CORP LEISMER 8-17-78-7

08-17-078-07w4


GRAIN SIZE
SAND
SILT
CLAY
c
m
f
vf
BIOTURB
FEET
POROSITY
BITUMEN
975
1000
1025
1050

lt gy mud, massive

silt, lt br, no stain, gradational contacts

Intb silt-sh, planolites, oil stained traces.

Ss, fg, oil stained, shale break burrowed, planolites.

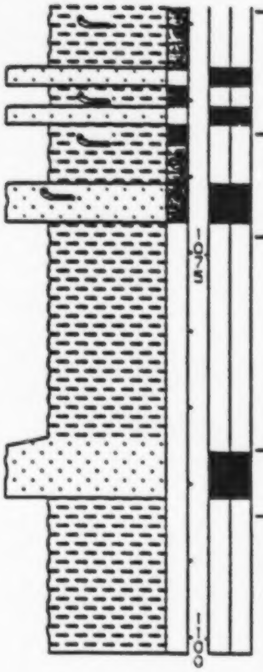
Ss, fg, oil stained, shale breaks

Ss, fg, shale breaks display planolites.

Ss, fg, only very light oil stain?, don't know why.

Mud, lt gy, planolites * Note, this 5 ft. core is at unknown depths within the interval 1026-1046.

thin laminated mud, planolites, some sand-shale alternating deposits as in tidal regime.



Sh, lt gy, small sand break oil stained, planolites present.

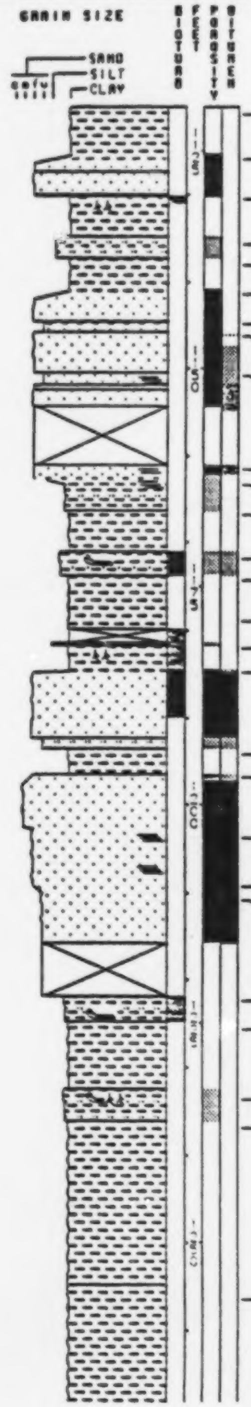
Alternating sand and shale packages, each over 25 cm, sand is oil stained, shale is burrowed with planolites, burrows are oil stained.

mud, lt gy, massive

Ss, fg, oil stained, gradational upper contact shows waning current

mud, lt gy, massive

ROC CORP. PONY CREEK 9-1 80-8
R O CORP. PONY CREEK 9-1-80-8
09-01-080-08wW4



shale, lt grey, gradational lower contact.

Ss. fg, lt brn, massive, erosional lower contact.

Sh. lt gy, some grass roots preserved.

silty shale, lt gy.

shale, ly gy, some sand clasts.

Ss. fg, lt gy-green, some plant root traces.

Ss., br. with thin, dk gy shale layers.

Ss. fg,lightly bitumen stained bottom grading into clean lt. br. Ss.

intb Ss-silt, light staining, planar laminated.

intb Ss-silt, lt bit. staining, planar laminated, s-s-d.

intb sh-Ss., thin sands in sh. grades upwards into Ss.

Sh. lt gy.

sandy shale, sand filled burrows. light staining

ly gy mud

some ss found in mud

ly gy mud, rooting

Ss. fg, bioturbated appearance of staining pattern.

lt gy mud, sand clasts

Ss, fg-mg, stained.

planar bedding.

coarsening up Ss. planar bedding

Ss. vfg, massive, good staining

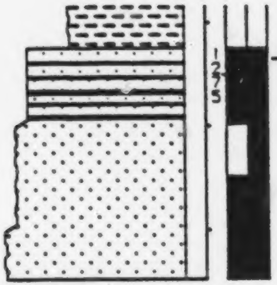
lt gy mud, intb sand, planolites.

ly gy mud

silty mud, bioturbated, planolites, rooting

lt gy mud

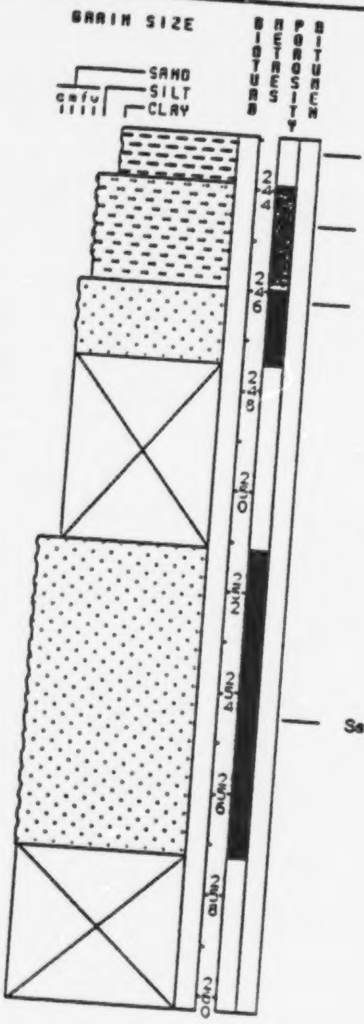
some intb silt clasts.



Se, fg, stained, some shale clasts and planolites in the shale

AMOCO A-6 LEISMER 11-34

11-34-077-08w4


GRAIN SIZE
SAND
SILT
CLAY
c m f v
BIOTURB
METRES
POROSITY
BITUMEN
244
246
248
250
252
254
256
258
260

Shale, lt gy, massive.

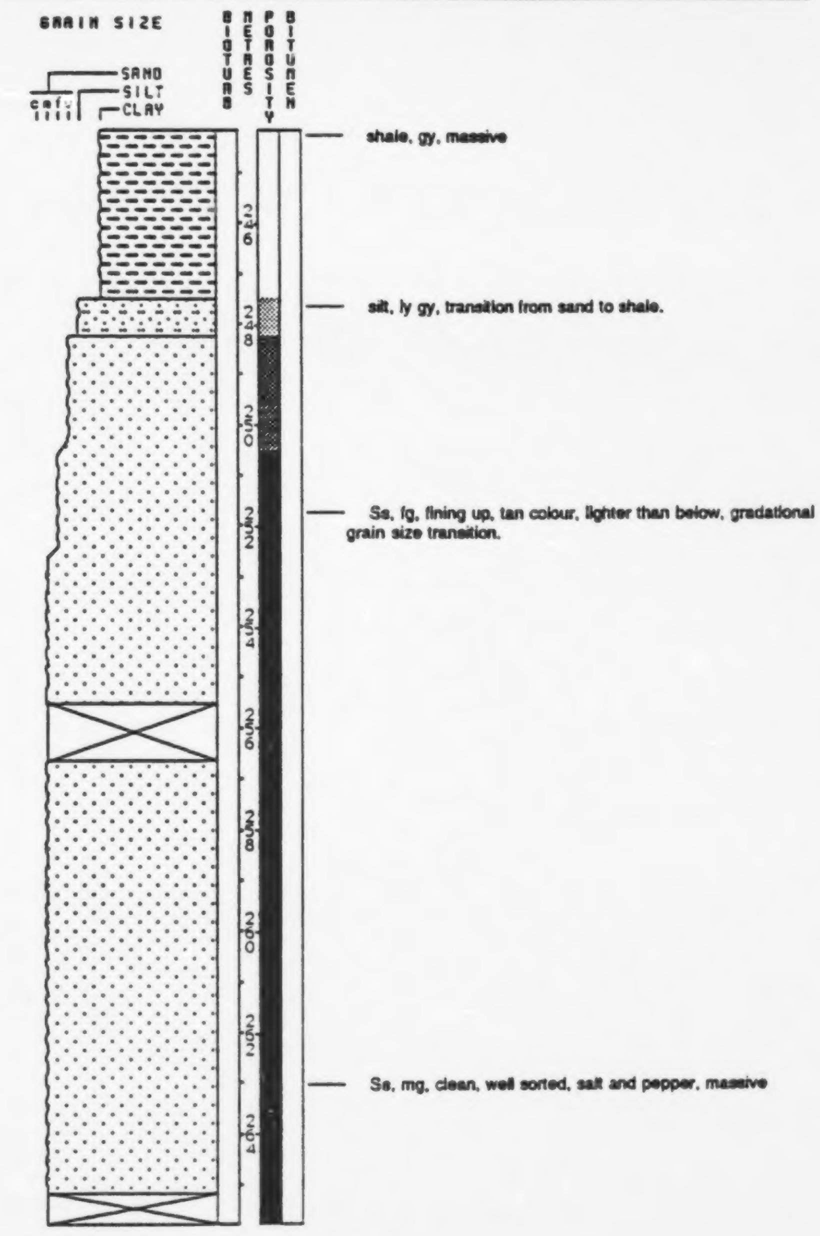
Siltstone, tan, massive

Ss, fg, massive, lt br.

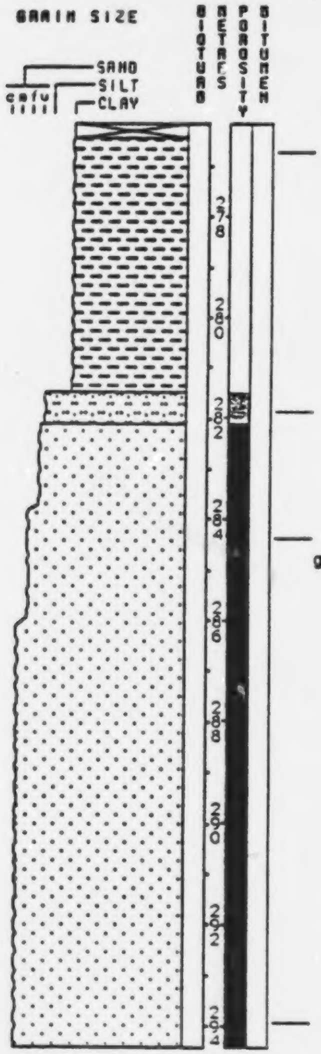
Ss, mg, salt and pepper, massive, some carb. clasts

AMOCO A-7LEISMER 6-22

06-22-077-08w4


GRAIN SIZE
SAND
SILT
CLAY
c m f v
BIOTURB
METRES
POROSITY
BITUMEN
246
248
250
252
254
256
258
260
262
264
shale, gy, massive
silt, ly gy, transition from sand to shale.
Ss, fg, fining up, tan colour, lighter than below, gradational grain size transition.
Ss, mg, clean, well sorted, salt and pepper, massive

AMOCO A-5 LEISMER 6-9
06-09-077-08W4


GRAIN SIZE
SAND
SILT
CLAY
c m f vf
BIOTURB
METRES
POROSITY
BITUMEN
278
280
282
284
286
288
290
292
294

shale, gy, massive

silt, lt gy, transition from sand to shale.

Ss, fg, fining up, tan colour, lighter than below, gradational grain size transition.

Ss, clean well sorted, salt & pepper, massive

Appendix B

Thesis Data

- Clearwater Fm. Structure
- Clearwater 'A' Structure
- Clearwater 'B' Structure
- Wabiskaw Member Structure
- McMurray Fm. Structure
- SubCretaceous Unconformity Structure
- Clearwater Fm. Isopach
- Clearwater 'A' ; Top 5 m Ss./Sh. Ratio
- Clearwater 'B' ; Top 15 m Ss./Sh. Ratio
- Wabiskaw Member Isopach
- McMurray Fm. Isopach
- McMurray Fm. ; Top 15 m Ss./Sh. Ratio
- Clearwater 'A' Net Pay
- Clearwater 'B' Net Pay
- Clearwater 'C' Net Pay
- Clearwater Fm. Net Pay
- Wabiskaw Member Net Pay
- McMurray Fm. Net Pay

lsd	sec	twp	rng	clw top	wab top	mcm top	dev top	kb	clw iso	wab iso	mcm iso	clw a pay	clw b pay	clw c pay	clw net	wab pay	mcm pay	net pay	clw a depth	clw b depth	kb	clw a top	clw b top	clw a facies	clw b facies	wab facies	mcm facies
11	07	076	03W4	295.0	220.0	215.0	138.0	620.0	75.0	5.0	77.0	0	0	0	0	0	0	0	332	361	620.0	288	259	100%	27	4	33
10	22	076	03W4	296.0	210.0	204.0	116.0	635.0	86.0	6.0	88.0	0	0	0	0	0	0	0	368	384	635.0	277	251	100%	60	4	66
14	33	076	03W4	tight																		0	0				
11	16	076	04W4	tight																		0	0				
13	17	076	04W4	330.0	254.0	248.0	185.0	626.0	76.0	6.0	63.0	0	2	4	6	2	8	16	300	333	626.0	318	293	100%	53	4	60
10	18	076	04W4	321.0	243.0	237.0	176.0	630.0	78.0	6.0	64.0	0	0	0	0	0	0	0	320	349	630.0	310	281	100%	12	2	16
13	19	076	04W4	325.0	249.0	244.0	177.0	593.0	76.0	5.0	67.0	0	0	0	0	2	4	6	279	304	593.0	314	289	100%	40	3	33
13	20	076	04W4	328.0	252.0	247.0	184.0	616.5	76.0	5.0	63.0	0	0	3	3	2	5	10	302.8	325.5	616.5	314	291	100%	20	3	33
10	21	076	04W4	323.0	241.0	234.0	159.0	603.0	82.0	7.0	75.0	0	0	0	0	0	0	0	294	322	603.0	300	281	100%	0	3	24
02	26	076	04W4	316.0	229.0	223.0	145.0	591.0	87.0	6.0	78.0	0	0	0	0	0	0	0	288	324	591.0	293	267	100%	33	4	87
10	27	076	04W4	322.0	239.0	234.0	157.0	596.0	83.0	5.0	77.0	0	0	0	0	0	0	0	288	317	596.0	307	279	100%	40	4	80
10	30	076	04W4	328.0	248.0	242.0	181.0	589.0	80.0	6.0	61.0	0	0	0	0	0	3	3	274	302	589.0	315	287	100%	67	6	33
07	31	076	04W4	330.0	250.0	245.0	181.0	582.0	80.0	5.0	64.0	0	0	0	0	2	2	4	264	292	582.0	318	290	100%	47	4	35
13	32	076	04W4	329.0	254.0	247.0	163.0	583.0	75.0	7.0	84.0	0	0	0	0	2	7	9	266	293	583.0	317	290	100%	20	4	73
15	35	076	04W4	311.0	237.0	231.0	136.0	581.0	74.0	6.0	95.0	0	0	0	0	2	0	2	270	305	581.0	305	276	100%	53	4	60
10	01	076	05W4	314.0	230.0	224.0	147.0	624.0	84.0	6.0	77.0	0	0	0	0	0	0	0	324	353	624.0	300	272	100%	50	4	16
10	05	076	05W4	312.0	253.0	250.0	N.P.	616.0	79.0	3.0	#######	0	0	0	0	1	5	6	293	318	616.0	323	298	100%	84	4	60
10	08	076	05W4	325.0	241.0	237.0	169.0	583.0	84.0	4.0	68.0	0	0	0	0	0	0	0	268	295	583.0	315	288	100%	80	4	27
16	10	076	05W4	312.0	234.0	230.0	N.P.	603.0	78.0	4.0	#######	0	0	0	0	0	0	0	289	320	603.0	304	274	100%	64	4	24
10	15	076	05W4	319.0	238.0	233.0	162.0	586.0	81.0	5.0	71.0	0	0	0	0	0	0	0	270	307	586.0	308	279	100%	73	4	13
10	16	076	05W4	314.0	235.0	230.0	140.0	584.0	79.0	5.0	90.0	0	0	0	0	0	0	0	280	309	584.0	304	275	100%	52	4	32
07	18	076	05W4	331.0	250.0	245.0	172.0	573.0	81.0	5.0	73.0	0	0	2	2	2	2	6	263	278	573.0	321	293	100%	67	3	27
04	25	076	05W4	321.0	245.0	241.0	105.0	597.0	76.0	4.0	46.0	0	0	0	0	0	2	2	277	313	597.0	320	284	100%	60	4	33
10	27	076	05W4	325.0	246.0	241.0	171.0	573.0	79.0	5.0	70.0	0	0	0	0	0	0	0	260	287	573.0	315	286	100%	27	3	33
10	29	076	05W4	323.0	243.0	240.0	157.0	559.0	80.0	3.0	83.0	0	0	0	0	0	0	0	246	275	559.0	313	284	100%	54	3	44
07	32	076	05W4	316.0	254.0	249.0	166.0	579.0	82.0	5.0	83.0	0	2	0	2	2	9	13	260	286	579.0	331	293	100%	33	3	47
06	34	076	05W4	330.0	256.0	251.0	174.0	573.0	74.0	5.0	77.0	0	3	0	3	0	5	8	263	279	573.0	320	294	100%	27	4	33
13	36	076	05W4	328.0	250.0	245.0	169.0	573.0	78.0	5.0	76.0	0	0	0	0	2	2	4	266	284	573.0	317	289	100%	40	3	67
11	01	076	06W4	340.0	256.0	248.0	190.0	599.0	84.0	8.0	58.0	0	0	2	2	1	0	3	260	292	599.0	331	307	100%	100	3	33
13	02	076	06W4	341.0	258.0	250.0	182.0	584.0	83.0	8.0	68.0	0	1	2	3	3	1	7	263	287	584.0	322	297	100%	100	6	20
11	03	076	06W4	333.0	252.0	249.0	172.0	594.0	81.0	3.0	77.0	0	0	0	0	0	1	1	271	294	594.0	325	300	100%	100	0	32
10	08	076	06W4	331.0	244.0	240.0	N.P.	584.0	87.0	4.0	#######	0	0	0	0	0	0	0	266	282	584.0	320	302	100%	100	1	32
11	14	076	06W4	337.0	257.0	252.0	N.P.	570.0	80.0	5.0	#######	0	3	0	3	0	1	4	243	265	570.0	327	307	100%	70	0	32
07	19	076	06W4	342.0	254.0	252.0	N.P.	571.0	88.0	2.0	#######	0	7	0	7	0	0	7	241	258	571.0	330	313	55%	100	0	28
06	26	076	06W4	335.0	254.0	252.0	178.0	570.0	81.0	2.0	74.0	0	0	0	0	0	0	0	246	267	570.0	324	303	80%	24	0	20
07	28	076	06W4	349.0	266.0	263.0	204.0	564.0	83.0	3.0	59.0	0	14	0	14	0	4	18	239	242	564.0	335	322	65%	100	0	30
11	31	076	06W4	347.0	259.0	256.0	N.P.	562.0	88.0	3.0	#######	0	12	0	12	0	0	12	232	248	562.0	330	314	75	100	0	N.P.
10	06	076	07W4	352.0	265.0	240.0	195.0	652.0	87.0	5.0	45.0	0	8	0	8	0	0	8	329	344	652.0	323	308	0	100	0	50
10	14	076	07W4	348.0	264.0	259.0	206.0	597.0	84.0	5.0	55.0	0	10	0	10	0	6	16	260	281	597.0	337	316	20	100	0	100
07	21	076	07W4	344.0	244.0	241.0	201.0	611.0	100.0	3.0	40.0	0	5	0	5	0	0	5	288	304	611.0	331	307	100	100	0	20
10	22	076	07W4																			0	0				
09	23	076	07W4																			0	0				
07	24	076	07W4	357.0	270.0	268.0	220.0	589.0	87.0	2.0	48.0	0	6	0	6	0	1	7	260	261	589.0	349	328	40	90	0	13
10	27	076	07W4	346.0	255.0	253.0	N.P.	573.0	91.0	2.0	#######	0	6	0	6	0	0	6	263	265	573.0	330	308	100	100	0	100
11	30	076	07W4	347.0	253.0	249.0	N.P.	572.0	94.0	4.0	#######	0	7	0	7	0	0	7	268	264	572.0	332	308	100	100	1	64
11	32	076	07W4	351.0	259.0	253.0	N.P.	559.0	92.0	6.0	#######	3	13	0	16	1	0	17	233	242	559.0	336	317	100	100	4	52
07	35	076	07W4	350.0	255.0	252.0	N.P.	565.5	95.0	3.0	#######	0	11	0	11	0	0	11	230.8	249.5	565.5	335	316	100	100	1	40
10	36	076	07W4	351.0	N.P.	N.P.	N.P.	567.6	#######	#######	#######	0	15	0	15	N.P.	N.P.	15	220.6	247.6	567.6	339	320	20	100	N.P.	N.P.
10	08	076	08W4	326.0	238.0	230.0	185.0	634.4	88.0	8.0	45.0	0	0	0	0	0	0	0	321.6	335.4	634.4	313	290	60	100	0	60
10	11	076	08W4	330.0	241.0	236.0	185.0	640.0	89.0	5.0	51.0	0	0	0	0	0	0	0	322	340	640.0	318	300	35	100	0	46
11	21	076	08W4	332.0	246.0	241.0	187.0	647.0	86.0	5.0	54.0	0	0	0	0	0	0	0	320	347	647.0	318	300	0	100	0	60
10	23	076	08W4	338.0	246.0	241.0	188.0	616.0	92.0	5.0	53.0	0	0	0	0	0	0	0	294	319	616.0	322	297	100	100	0	64
10	32	076	08W4	338.0	252.0	249.0	197.0	618.0	86.0	3.0	52.0	0	5	0	5	0	0	5	294	310	618.0	324	308	0	100	0	72
07	20	076	09W4	323.0	240.0	238.0	190.0	682.0	83.0	4.0	46.0	0	0	0	0	0	0	5	372	387	682.0	310	295	0	100	0	33
07	21	076	09W4	324.0	243.0	239.0	196.0	686.8	81.0	4.0	43.0	0	0	0	0	0	0	0	370.8	385.8	686.8	316	301	0	100	0	35
10	26	076	09W4	327.0	246.0	242.0	195.0	654.0	81.0	4.0	47.0	0	0	0	0	0	0	0	335	350	654.0	319	304	0	100	1	60

10	01	076	10W4	318.0	228.0	225.0	200.0	683.5	90.0	3.0	16.0	0	0	0	0	0	0	2	376.8	397.5	683.5	307	286	0	100	0	60
14	04	076	10W4	321.0	228.0	225.0	188.0	665.5	93.0	3.0	37.0	0	0	0	0	0	0	5	362.5	378.5	665.5	303	287	0	100	0	27
12	13	076	10W4	326.0	241.0	237.0	213.0	667.0	85.0	4.0	24.0	0	0	0	0	0	0	0	344	372	667.0	313	295	0	100	0	53
13	15	076	10W4	319.0	234.0	231.0	207.0	642.0	85.0	3.0	24.0	0	0	0	0	0	0	0	334	351	642.0	308	291	0	100	0	56
04	17	076	10W4	318.0	228.0	225.0	173.0	672.0	90.0	3.0	52.0	0	0	0	0	0	0	0	366	384	672.0	306	288	0	100	3	67
10	24	076	10W4	328.0	242.0	235.0	214.0	660.5	86.0	7.0	21.0	0	0	0	0	0	0	0	346.6	362.5	660.5	315	298	0	100	1	100
08	34	076	10W4	324.0	246.0	243.0	209.0	642.0	78.0	3.0	34.0	0	0	0	0	0	0	0	328	341	642.0	317	301	0	100	0	60
10	05	076	11W4	308.0	216.0	212.0	158.0	666.0	92.0	4.0	54.0	0	0	0	0	0	0	0	372	393	666.0	294	273	80	100	0	20
10	06	076	11W4	304.0	N.P.	N.P.	N.P.	669.0	######	#######	#######	0	0	0	0	N.P.	N.P.	0	378	398	669.0	291	271	80	100	N.P.	N.P.
07	17	076	11W4	310.0	220.0	214.0	162.0	671.0	90.0	6.0	52.0	0	0	0	0	0	0	0	372	393	671.0	299	278	40	100	0	36
05	19	076	11W4	303.0	219.0	216.0	N.P.	660.0	84.0	3.0	#######	0	0	0	0	0	0	0	367	386	660.0	293	274	100	100	0	50
10	23	076	11W4	318.0	227.0	223.0	170.0	670.0	91.0	4.0	53.0	0	0	0	0	0	0	0	369	387	670.0	301	283	0	100	1	40
10	27	076	11W4	315.0	229.0	223.0	169.0	668.0	86.0	6.0	54.0	0	0	0	0	0	0	0	368	383	668.0	303	285	0	100	3	56
07	36	076	11W4	323.0	236.0	229.0	180.0	678.0	87.0	7.0	49.0	0	0	0	0	0	0	0	367	383	678.0	311	295	80	100	1	30
06	03	077	03W4	305.0	224.0	218.0	111.0	591.0	81.0	6.0	107.0	0	0	0	0	0	0	0	303	328	591.0	288	263	100	20	3	47
14	33	077	03W4	tight																							
11	34	077	03W4	321.0	244.0	238.0	142.0	592.0	77.0	6.0	96.0	0	0	0	0	0	0	0	287	312	592.0	305	280	100	55	3	27
11	02	077	04W4	318.0	242.0	235.0	148.0	580.2	76.0	7.0	87.0	0	0	0	0	2	3	5	276.2	302.2	580.2	305	278	100	40	4	60
11	03	077	04W4	319.5	243.0	235.5	137.0	581.5	76.5	7.5	98.5	0	0	0	0	2	8	10	276.8	301.5	581.5	306	280	100	47	4	55
09	06	077	04W4	334.0	257.0	231.0	N.P.	579.8	77.0	6.0	#######	0	0	0	0	0	3	3	266	284	579.8	313.8	295.8	100	50	3	40
07	07	077	04W4	324.0	250.0	243.0	170.0	583.0	74.0	7.0	73.0	0	0	0	0	1	3	4	270	295	583.0	313	288	100	60	3	47
12	11	077	04W4	307.0	233.0	227.0	142.0	583.7	74.0	6.0	85.0	0	0	0	0	1	2	3	290	313	583.7	293.7	270.7	100	47	3	67
02	14	077	04W4	306.0	221.0	214.0	130.0	575.7	85.0	7.0	84.0	0	0	0	0	0	0	0	296	317	575.7	280.7	258.7	100	50	2	53
03	15	077	04W4	320.0	246.0	239.0	144.0	574.0	74.0	7.0	95.0	0	0	0	0	2	8	10	267	290	574.0	307	284	100	50	3	80
02	18	077	04W4	332.0	249.0	243.0	N.P.	583.4	83.0	6.0	#######	0	0	0	0	2	10	12	276	297	583.4	308.4	286.4	100	50	3	80
03	19	077	04W4	330.0	253.0	245.0	163.0	566.2	77.0	8.0	82.0	0	0	0	0	2	10	12	263	275	566.2	313.2	290.2	100	60	3	67
06	20	077	04W4	311.0	243.0	238.0	140.0	577.5	66.0	7.0	98.0	0	0	0	0	2	2	4	273	295	577.5	304.5	282.5	100	50	3	67
10	27	077	04W4	303.0	234.7	228.3	132.9	566.0	68.3	6.4	95.4	0	0	0	0	2	2	4	267	311	566.0	299	275	100	50	2	20
13	29	077	04W4	319.0	240.0	234.0	150.0	593.0	79.0	6.0	84.0	0	1	0	1	0	2	3	291	315	593.0	302	278	100	50	3	60
07	30	077	04W4	327.0	253.0	247.0	162.0	575.0	74.0	6.0	85.0	0	0	0	0	1	6	7	268	286	575.0	310	289	100	50	3	65
02	31	077	04W4	321.0	251.0	244.0	164.0	565.0	70.0	7.0	80.0	0	0	0	0	2	8	10	262	278	565.0	303	287	100	50	3	87
00	34	077	04W4	319.0	263.0	250.0	139.0	591.0	56.0	13.0	91.0	0	0	0	0	1	9	10	272	296	591.0	319	295	100	50	2	80
06	35	077	04W4	316.0	254.0	247.0	156.0	583.0	62.0	7.0	91.0	0	0	0	0	1	2	3	270	293	583.0	313	290	100	50	3	60
03	01	077	05W4	332.0	256.0	248.0	176.0	575.0	78.0	6.0	72.0	0	0	0	0	0.5	6.5	7	264	282	575.0	321	293	100	50	3	87
05	03	077	05W4	338.0	257.0	252.0	180.0	570.3	81.0	5.0	72.0	0	2	2	4	4	17	25	247	273	570.3	323.3	297.3	100	50	3	87
11	04	077	05W4	331.5	258.0	251.0	174.5	578.5	73.5	7.0	76.5	0	0	0	0	0	3	3	261	286	578.5	317.5	292.5	100	50	0	40
06	05	077	05W4	334.0	252.0	247.0	162.0	583.8	82.0	5.0	85.0	0	1	0.5	1.5	2.5	5	9	260	292	583.8	315.8	291.8	100	50	3	60
06	09	077	05W4	321.0	247.0	239.0	151.0	586.3	74.0	8.0	88.0	0	0	0	0	0	2	2	276	298	586.3	311.3	288.3	100	50	4	80
05	10	077	05W4	324.0	248.0	243.0	169.0	583.6	76.0	5.0	74.0	0	0	0	0	0	4	4	272	297	583.6	311.6	286.6	100	50	3	33
07	11	077	05W4	330.0	249.0	244.0	171.0	578.4	81.0	5.0	73.0	0	0	0	0	0.5	2.5	3	263	289	578.4	315.4	289.4	100	50	3	33
05	12	077	05W4	332.0	250.0	244.0	164.0	581.0	82.0	6.0	80.0	0	0	0	0	0	4	4	266	292	581.0	315	290	100	50	3	53
04	13	077	05W4	321.0	244.0	238.0	178.0	573.3	77.0	6.0	60.0	0	0	0	0	0	3	3	267	290	573.3	306.3	283.3	100	50	3	73
08	20	077	05W4	333.0	252.0	247.0	174.0	574.0	81.0	5.0	73.0	0	0	0	0	1	2	3	267	281	574.0	317	295	100	50	3	20
11	21	077	05W4	334.0	255.0	250.0	168.0	574.2	79.0	5.0	82.0	0	2	0	2	1	6	9	266	280	574.2	318.2	294.2	100	50	2	53
09	22	077	05W4	331.0	250.0	244.0	165.0	585.0	81.0	6.0	79.0	0	0	0	0	1	2	3	272	296	585.0	313	289	100	50	2	73
12	25	077	05W4	323.0	260.0	253.0	166.0	588.7	63.0	7.0	85.0	0	0	0	0	1	15	16	271	292	588.7	317.7	296.7	100	50	2	100
09	27	077	05W4	338.0	258.0	251.0	168.0	584.0	78.0	7.0	83.0	0	1.5	0.5	2	2	11	15	265	288	584.0	319	296	100	50	2	100
11	28	077	05W4	334.0	253.0	248.0	171.0	574.2	81.0	5.0	77.0	0	0	0	0	1	4	5	268	282	574.2	316.2	292.2	100	50	3	40
10	29	077	05W4	333.0	250.5	245.0	161.5	578.5	82.5	5.5	83.5	0	0	0	0	1	3	4	264	288	578.5	314.5	290.5	100	50	2	20
11	31	077	05W4	tight																							
10	33	077	05W4	334.0	250.0	245.0	172.0	583.9	84.0	5.0	73.0	0	0	0	0	1	6	7	271	296	583.9	312.9	287.9	100	50	2	33
10	34	077	05W4	331.0	252.0	245.6	N.P.	580.6	79.0	6.4	#######	0	0	0	0	1	6	7	268	290	580.6	312.6	290.6	100	50	2	80
10	36	077	05W4	323.0	253.0	246.0	160.0	581.5	60.0	7.0	77.0	0	0	0	5	1	6	7	270	292	581.5	311.5	289.5	100	50	3	67
10	03	077	06W4	353.0	259.4	254.0	N.P.	562.3	95.6	5.4	#######	0	0	2	2	0	0	2	210	235	562.3	344.3	327.3	40	70	N.P.	N.P.
10	05	077	06W4	340.0	260.6	256.3	200.3	574.5	80.3	4.3	56.0	0	7	1	8	0	8	8	230	258	574.5	335.5	316.5	100	100	2	40
11	07	077	06W4	344.0	254.0	253.0	204.5	565.7	85.0	4.0	50.5	0	9	0	9	0	0	9	230	251	565.7	334.7	314.7	100	100	2	20
07	13	077	06W4	331.0	253.0	246.0	101.0	566.5	78.0	7.0	65.0	0	0	0	0	0	2	2	247	272	566.5	319.5	294.5	100	70	1	67

11	14	077	06W4	337.0	251.0	246.0	166.0	569.0	86.0	5.0	80.0	0	0	0	0	0	0	0	240	276	569.0	310	298	100	50	2	38
06	16	077	06W4	347.0	259.0	253.4	210.0	569.8	88.0	3.6	65.4	0	0	0	0	0	0	0	239	265	569.8	330.8	304.8	100	76	2	13
10	22	077	06W4	tight																							
07	25	077	06W4	339.0	255.0	250.0	155.0	569.0	84.0	5.0	95.0	0	0	0	0	0	4	4	246	272	569.0	321	297	100	50	2	60
11	27	077	06W4	tight																		0	0				
10	31	077	06W4	tight																		0	0				
06	32	077	06W4	tight																		0	0				
09	36	077	06W4	tight																		0	0				
10	01	077	07W4	353.0	260.6	256.0	199.0	563.6	92.4	4.6	57.0	4	6	0	10	0	0	10	233	245	563.6	340.6	318.6	100	100	2	76
11	03	077	07W4	349.0	259.0	255.0	203.0	564.2	90.0	4.0	52.0	0	12	0	12	0	0	12	231	248	564.2	333.2	316.2	100	100	2	44
10	04	077	07W4	360.0	263.0	258.0	205.0	569.5	77.0	5.0	55.0	0	15	0	15	0	2	15	232	251	569.5	337.5	318.5	100	100	2	80
12	05	077	07W4	348.7	257.0	252.0	203.0	563.7	91.7	5.0	49.0	0	9	0	9	0	0	9	239	248	563.7	334.7	315.7	100	100	2	35
11	06	077	07W4	347.0	259.0	254.0	201.0	575.6	88.0	5.0	53.0	0	7	0	7	0	0	7	229	263	575.6	346.6	312.6	100	100	0	15
03	07	077	07W4	296.0	256.0	252.0	202.0	572.0	40.0	4.0	50.0	0	6	0	6	0	0	6	240	258	572.0	332	314	100	100	2	0
06	07	077	07W4	347.0	261.0	256.0	206.0	565.0	86.0	5.0	50.0	0	9	0	9	0	0	9	232	253	565.0	333	312	100	100	0	20
11	08	077	07W4	345.0	255.0	250.0	204.0	563.3	90.0	5.0	66.0	0	6	0	6	0	0	6	235	252	563.3	326.3	311.3	100	100	2	30
11	09	077	07W4	348.0	263.0	258.0	205.5	567.0	85.0	5.0	52.5	0	13	0	13	0	0	13	233	249	567.0	334	318	100	100	0	28
11	10	077	07W4	352.6	267.0	262.0	205.0	567.6	85.6	5.0	57.0	0	14	0	14	0	0	14	230	249	567.6	337.6	318.6	100	100	0	27
07	11	077	07W4	356.0	266.0	261.0	N.P.	564.0	90.0	5.0	#######	3	13	0	16	0	0	18	226	245	564.0	340	319	100	100	0	27
11	15	077	07W4	350.0	267.0	262.0	203.0	571.0	85.0	5.0	50.0	0	10	0	10	0	0	10	238	256	571.0	333	315	100	100	0	23
11	17	077	07W4	353.0	266.0	251.0	N.P.	562.9	87.0	5.0	#######	0	16	0	16	1	1	18	221	242	562.9	339.9	320.9	100	100	2	33
11	18	077	07W4	351.0	N.P.	N.P.	N.P.	562.2	######	#######	#######	0	11	0	11	N.P.	N.P.	11	227	242	562.2	335.2	320.2	100	100	N.P.	N.P.
11	19	077	07W4	349.0	259.0	255.0	206.0	556.0	90.0	4.0	49.0	0	11	0	11	0	0	11	224	238	556.0	332	318	100	100	2	40
11	21	077	07W4	349.0	260.5	258.0	207.0	560.5	88.7	2.5	51.0	0	9	0	9	0	0	9	237	246	560.5	333.5	314.5	100	100	0	15
06	24	077	07W4	349.0	265.0	262.0	208.0	569.3	84.0	3.0	54.0	0	3	0	3	0	0	3	236	261	569.3	333.3	308.3	100	80	1	75
10	25	077	07W4	347.0	264.0	261.5	206.3	580.6	83.0	2.5	55.2	0	1	0	1	0	0	1	250	276	580.6	330.6	304.6	100	80	2	13
06	27	077	07W4	350.0	269.0	266.0	N.P.	562.0	81.0	3.0	#######	0	5	0	5	0	0	5	224	251	562.0	338	311	100	70	0	40
10	29	077	07W4	349.0	269.0	266.7	211.0	555.3	80.0	2.5	55.7	0	6	0	6	1	0	7	223	246	555.3	332.3	309.3	100	100	2	76
11	01	077	08W4	350.0	261.0	258.5	207.3	570.9	89.0	2.5	51.2	0	12	0	12	0	2	14	230	251	570.9	340.9	318.9	100	100	2	72
11	02	077	08W4	345.0	257.0	254.0	N.P.	579.1	88.0	3.0	#######	0	9	0	9	0	1	10	249	262	579.1	330.1	317.1	100	100	2	60
10	03	077	08W4	343.0	255.0	251.5	194.0	586.7	88.0	3.5	57.5	0	7	0	7	0	1	8	250	272	586.7	328.7	314.7	80	100	2	62
02	08	077	08W4	340.0	252.5	249.0	193.5	584.0	87.5	3.5	55.5	0	4	0	4	0	N.P.	4	259	273	584.0	325	311	60	100	2	60
15	08	077	08W4	345.0	257.0	254.0	N.P.	579.0	86.0	3.0	#######	0	6.5	0	6.5	0	0.5	7	249	264	579.0	330	315	50	100	2	80
06	09	077	08W4	340.0	269.3	265.7	N.P.	590.0	90.7	3.6	#######	0	8	0	8	0	N.P.	8	264	280	590.0	326	310	60	100	2	N.P.
10	10	077	08W4	346.0	256.0	253.0	N.P.	585.3	90.0	3.0	#######	0	6	0	6	0	1	7	268	271	585.3	330.3	314.3	80	100	2	60
11	11	077	08W4	344.0	256.3	253.0	N.P.	570.6	87.7	3.3	#######	0	8	0	8	0	N.P.	8	243	255	570.6	327.6	315.6	60	100	2	N.P.
03	12	077	08W4	342.0	251.0	249.0	N.P.	567.0	91.0	2.0	#######	0	5	0	5	0	0	5	242	255	567.0	325	312	60	100	0	33
10	13	077	08W4	346.0	N.P.	N.P.	N.P.	557.5	######	#######	#######	0	9	0	9	0	0	9	230	242	557.5	327.5	315.5	100	100	N.P.	N.P.
07	14	077	08W4	346.0	257.0	254.0	N.P.	568.0	89.0	3.0	#######	0	10	0	10	0	1	11	239	252	568.0	329	316	80	100	2	47
10	18	077	08W4	344.0	253.6	249.3	N.P.	576.7	90.4	4.3	#######	0	7	0	7	0	N.P.	7	247	264	576.7	329.7	312.7	50	100	N.P.	N.P.
10	19	077	08W4	tight																		0	0				
10	20	077	08W4	346.3	257.3	253.3	N.P.	267.5	89.0	4.0	#######	0	7	0	7	0	N.P.	7	236	254	267.5	31.5	13.5	100	100	N.P.	N.P.
10	21	077	08W4	tight																		0	0				
06	22	077	08W4	344.4	257.6	254.0	N.P.	559.6	86.8	3.6	#######	0	10	0	10	0.5	0.5	11	237	246	559.6	322.6	313.6	100	100	N.P.	N.P.
04	23	077	08W4	344.5	255.5	248.5	N.P.	562.5	89.0	7.0	#######	0	8	0	8	0	0	8	233	247	562.5	329.5	315.5	80	100	3	60
06	24	077	08W4	350.0	258.0	255.0	N.P.	557.0	92.0	3.0	#######	0	8	0	8	1	0	9	223	240	557.0	334	317	100	100	2	0
06	25	077	08W4	346.0	256.0	252.0	N.P.	556.4	90.0	4.0	#######	0	9	0	9	0	0	9	226	250	556.4	331.4	306.4	100	100	3	0
11	27	077	08W4	tight																		0	0				
10	28	077	08W4	345.3	260.3	255.7	205.1	561.7	85.0	4.6	50.6	0	8	0	8	1	0	9	231	246	561.7	330.7	315.7	80	100	2	40
10	29	077	08W4	tight																		0	0				
06	30	077	08W4	tight																		0	0				
06	31	077	08W4	tight																		0	0				
11	34	077	08W4	346.6	260.6	256.3	N.P.	556.3	86.0	4.3	#######	0	8	0	8	0	0	8	226	241	556.3	331.3	315.3	80	100	N.P.	N.P.
11	06	077	09W4	328.0	247.0	243.0	N.P.	631.0	81.0	4.0	#######	0	3	0	3	0	0	3	311	324	631.0	320	307	0	100	4	53
06	11	077	09W4	337.7	247.0	244.0	N.P.	635.8	90.7	3.0	#######	0	2	0	2	0	0	2	309	329	635.8	326.8	306.8	0	100	3	80
11	18	077	09W4	332.0	254.2	248.4	N.P.	619.7	77.8	5.5	#######	0	8	0	8	1	0	9	296	310	619.7	323.7	300.7	0	100	3	N.P.
10	22	077	09W4	342.3	257.0	252.7	205.7	586.0	85.3	4.5	47.0	0	7	0	7	1	1	9	250	274	586.0	328	313	0	100	3	40

15	33	077	09W4	343.0	258.8	254.5	N.P.	591.6	84.2	4.3	#######	0	9	0	9	1	2	12	244	278	591.6	327.6	313.6	0	100	4 N.P.	
06	34	077	09W4	342.0	255.0	250.5	N.P.	573.0	87.0	4.5	#######	0	6	0	6	0	0	6	246	261	573.0	327	312	40	100	2 N.P.	
10	25	077	09W4	346.0	261.0	256.0	N.P.	576.7	85.0	5.9	#######	0	11	0	11	1	1	13	246.7	260.7	576.7	331	316	30	100	4 N.P.	
10	25	077	09W4	tight																		0	0				
15	26	077	09W4	345.7	261.0	255.7	N.P.	582.7	84.7	5.3	#######	0	11	0	11	0	0	11	282.7	265.7	582.7	330	317	0	100	4	67
10	27	077	09W4	tight																		0	0				
07	29	077	09W4	342.0	257.7	252.0	N.P.	584.1	84.3	5.7	#######	0	8	0	8	1	1	10	260	271	584.1	326.1	313.1	0	100	2 N.P.	
10	35	077	09W4	tight																		0	0				
06	36	077	09W4	tight																		0	0				
11	13	077	10W4	322.8	249.0	245.4	218.0	633.0	73.8	3.6	27.4	0	4	0	4	0	2	6	314	327	633.0	319	306	0	100	1	40
10	14	077	10W4	328.0	249.0	243.0	200.0	635.0	79.0	6.0	43.0	0	3	0	3	2	1	6	316	320	635.0	319	306	20	100	3	20
02	25	077	10W4	336.0	248.0	242.0	192.0	614.2	88.0	6.0	50.0	0	4	0	4	0	0	4	296	309	614.2	318.2	305.2	20	100	4	40
08	29	077	10W4	323.1	241.4	234.7	181.7	665.0	81.7	6.7	53.0	0	0	0	0	0	0	0	264	367	665.0	311	298	0	100	1	36
09	11	077	11W4	318.0	237.0	231.0	175.0	681.6	81.0	6.0	56.0	0	0	0	0	0	0	0	273	387	681.6	308.6	294.6	20	100	2	13
11	15	077	11W4	tight																		0	0				
10	22	077	11W4	320.6	242.0	237.7	180.0	691.3	78.6	4.3	57.7	0	0	0	0	0	3	3	301	394	691.3	310.3	297.3	20	100	1	36
11	32	077	11W4	320.0	241.4	236.2	188.0	689.5	78.6	5.2	48.2	0	0	0	0	0	0	0	302	393	689.5	307.5	296.5	0	100	1	36
08	17	078	03W4	330.0	253.0	246.0	148.0	570.0	77.0	7.0	98.0	0	0	0	0	1	1	2	261	281	570.0	300	289	100	67	3	67
07	19	078	03W4	335.0	264.0	257.0	152.0	560.0	71.0	7.0	105.0	0	0	0	0	1	13	14	244	280	560.0	316	300	100	33	3	100
07	29	078	03W4	tight																		0	0				
07	30	078	03W4	tight																		0	0				
15	31	078	03W4	tight																		0	0				
07	32	078	03W4	333.0	262.0	255.0	160.0	553.0	71.0	7.0	95.0	0	0	0	0	2	9	11	243	256	553.0	310	297	100	60	4	100
05	01	078	04W4	315.0	236.0	228.0	136.0	580.5	79.0	8.0	92.0	0	0	0	0	0	0	0	283	307	580.5	297.5	273.5	100	27	4	47
06	02	078	04W4	tight																		0	0				
15	04	078	04W4	336.0	259.0	254.0	174.0	577.6	77.0	5.0	80.0	0	1	0	1	2	2	5	260	282	577.6	317.6	295.6	100	67	3	30
15	09	078	04W4	327.0	252.0	246.0	171.0	583.1	75.0	6.0	75.0	0	0	0	0	1	1	2	276	294	583.1	307.1	280.1	100	33	3	87
03	10	078	04W4	334.0	255.0	248.6	164.0	582.6	79.0	6.4	84.6	0	0	0	0	1	2	3	260	290	582.6	314.6	292.6	100	33	4	47
05	15	078	04W4	330.0	260.0	253.0	168.0	566.5	70.0	7.0	85.0	0	0	0	0	1	10	11	253	271	566.5	313.5	295.5	100	33	3	100
07	16	078	04W4	333.0	261.0	254.0	170.0	559.0	74.0	7.0	84.0	0	0	1	1	2	12	15	248	262	559.0	314	297	100	20	3	100
06	19	078	04W4	334.0	258.0	251.0	194.0	566.0	76.0	7.0	57.0	0	0	0	0	1	2	3	283	270	566.0	313	296	100	60	3	13
06	20	078	04W4	325.0	254.0	248.0	178.0	563.8	71.0	6.0	70.0	0	0	0	0	1	3	4	286	272	563.8	307.8	291.8	100	47	3	20
07	21	078	04W4	317.0	257.0	250.5	171.0	564.5	60.0	6.5	79.5	0	0	0	0	1	3	4	264.5	275.5	564.5	311	296	100	33	3	20
06	22	078	04W4	329.0	255.0	251.0	163.0	558.4	74.0	4.0	88.0	0	0	0	0	1	1	2	249.4	268.4	558.4	309	290	100	33	2	20
10	25	078	04W4	339.0	267.0	259.0	156.0	564.2	72.0	8.0	100.0	0	1	0	1	1	13	14	246.2	260.2	564.2	318	304	100	47	3	73
12	27	078	04W4	316.7	243.0	237.0	154.0	560.0	73.7	6.0	83.0	0	0	0	0	1	3	4	270	285	560.0	296	281	100	10	1	20
10	30	078	04W4	336.0	261.0	256.5	183.0	564.5	75.0	4.5	73.5	0	0	1	1	1	2	4	262.5	266.5	564.5	312	298	100	47	1	33
12	36	078	04W4	332.0	259.0	253.6	152.0	557.6	73.0	4.0	103.0	0	0	0	0	1	4	5	249.6	261.6	557.6	308	296	100	33	1	80
08	01	078	05W4	337.0	250.0	244.0	163.0	573.1	87.0	6.0	81.0	0	0	0	0	1	2	3	266	288	573.1	300.1	287.1	100	33	4	87
05	06	078	05W4	339.0	256.0	251.0	175.0	589.8	83.0	5.0	76.0	0	0	0	0	1	3	4	273	295	589.8	316.8	294.2	100	33	3	27
08	05	078	05W4	339.0	255.0	249.0	175.0	580.6	84.0	6.0	74.0	1	0	0	1	1	4	6	262.6	285.6	580.6	318	295	100	40	2	33
03	07	078	05W4	333.0	257.0	252.0	162.0	581.7	78.0	5.0	90.0	0	0	0	0	1	8	9	270.7	290.7	581.7	315	293	100	47	2	67
05	08	078	05W4	336.0	259.0	254.0	175.0	576.0	77.0	5.0	79.0	0	1	0	1	1	6	8	260	279	576.0	316	297	100	33	2	33
06	12	078	05W4	325.0	249.0	244.0	167.0	578.5	76.0	5.0	77.0	0	0	0	0	1	2	3	273.5	291.5	578.5	305	287	100	40	2	47
08	14	078	05W4	333.0	257.0	251.0	175.0	579.0	78.0	6.0	76.0	0	0	0	0	1	4	5	266	286	579.0	313	295	100	33	3	60
07	15	078	05W4	316.1	235.9	229.8	142.3	575.2	80.2	6.1	87.5	0	0	0	0	0	0	0	260	299	575.2	295.2	276.2	100	60	3	60
07	16	078	05W4	329.0	251.0	246.0	155.0	579.8	78.0	5.0	91.0	0	0	0	0	0	0	0	271	289	579.8	308.8	290.8	100	33	3	47
06	17	078	05W4	330.0	253.0	248.0	165.0	580.8	77.0	5.0	83.0	0	0	0	0	1	0	1	271	289	580.8	309.8	291.8	100	33	2	33
05	21	078	05W4	329.0	262.0	257.0	169.0	579.5	67.0	5.0	88.0	0	0	0	0	0	3	3	268	281	579.5	314.5	298.5	100	40	2	67
03	23	078	05W4	334.0	264.0	258.0	186.0	564.9	70.0	6.0	72.0	0	1	0	1	1	7	9	261	267	564.9	313.9	297.9	100	47	3	93
07	26	078	05W4	342.0	268.0	261.0	187.0	570.1	74.0	7.0	74.0	2	3	1	6	1	11	18	260.1	275.1	570.1	319	304	100	40	3	100
06	30	078	05W4	333.0	257.0	252.0	172.0	555.8	76.0	5.0	80.0	0	0	0	0	0	1	1	262	266	555.8	313.8	287.8	100	33	3	60
04	31	078	05W4	335.0	258.0	253.0	173.0	527.0	77.0	5.0	78.0	0	0	0	0	0	0	0	316	228	527.0	313	290	100	47	2	60
03	34	078	05W4	327.0	255.0	250.0	177.0	532.4	72.0	5.0	73.0	0	0	0	0	0	1	1	226	230	532.4	306.4	293.4	100	60	2	60
01	35	078	05W4	tight																		0	0				
13	01	078	06W4	333.0	254.0	249.0	N.P.	597.0	81.0	4.2	#######	0	0	0	0	0	1	1	279.0	302.0	597.0	310	295	100	60	1	40
14	02	078	06W4	338.0	256.0	251.0	N.P.	610.5	82.0	5.0	#######	0	0	0	0	0	0	0	289.3	313.3	610.5	321	297	100	47	1	33

03	03	078	05W4	339.0	253.0	249.0	189.0	606.6	86.0	4.0	60.0	0	0	0	0	0	0	0	286.6	314.6	606.6	320	292	100	30	3	20
11	05	078	05W4	343.0	261.0	255.0	210.0	593.0	82.0	6.0	45.0	0	0	0	0	0	0	0	247	290	593.0	326	305	100	33	3	33
03	06	078	06W4	tight																		0	0				
11	08	078	06W4	343.0	265.0	258.0	208.0	579.0	78.0	7.0	50.0	0	2	1	2	1	1	4	263	274	579.0	326	305	100	60	1	67
12	11	078	06W4	tight																		0	0				
11	14	078	06W4	341.0	265.0	259.0	179.0	596.3	76.0	6.0	80.0	0	3	0	3	1	11	15	276.3	293.3	596.3	320	305	100	47	2	66
07	21	078	06W4	336.0	258.0	249.0	189.0	555.0	78.0	8.0	60.0	0	0	0	0	0	0	0	241	257	555.0	314	298	100	60	2	67
01	22	078	06W4	341.0	263.0	256.0	N.P.	566.0	78.0	5.0	########	0	0	0	0	0	6	6	243	265	566.0	324	305	100	47	3	33
07	23	078	06W4	327.0	255.0	250.0	N.P.	562.6	72.0	5.0	########	0	0	0	0	0	1	1	252.6	268.6	562.6	310	294	100	47	1	73
01	27	078	06W4	338.0	259.0	254.0	N.P.	546.0	79.0	5.0	########	0	0	0	0	0	5	5	231	247	546.0	315	299	100	60	1	67
11	30	078	06W4	331.0	254.0	249.0	186.0	564.0	77.0	5.0	63.0	0	0	0	0	0	0	0	263	268	564.0	311	296	100	47	2	47
07	33	078	06W4	343.0	268.0	259.0	200.0	554.3	75.0	9.0	59.0	0	1	0	1	1	6	8	236	249	554.3	318.3	303.3	60	33	3	60
05	34	078	06W4	337.0	267.0	263.3	192.6	556.6	70.0	3.7	70.7	0	0	0	0	0	2	2	241	234	556.6	315.6	302.6	100	44	1	36
13	34	078	06W4	336.0	260.0	252.0	N.P.	544.0	76.0	8.0	########	0	0	0	0	0	2	2	230	243	544.0	314	304	80	33	2	40
11	35	078	06W4	D.W.	260.0	255.0	N.P.	553.0	######	5.0	########	0	0	0	0	0	3	3	D.W.	D.W.	553.0	D.W.	D.W.	D.W.	D.W.	1	60
11	36	078	06W4	332.0	262.0	256.0	168.0	537.3	70.0	6.0	88.0	0	0	0	0	0	2	2	228.3	238.3	537.3	312	299	70	47	1	60
06	11	078	07W4	347.0	266.0	260.3	197.2	537.0	81.0	5.7	63.1	0	1	0	1	0	0	1	207	226	537.0	330	311	100	28	2	68
06	16	078	07W4	348.7	271.6	264.3	N.P.	549.0	77.1	7.3	########	1	3	3	7	1	0	8	217	235	549.0	332	314	100	28	3	80
08	17	078	07W4	346.6	268.0	257.0	217.3	552.6	78.6	11.0	39.7	0	3	0	3	1	0	4	226	242	552.6	324.6	310.6	100	44	2	58
11	17	078	07W4	347.2	270.0	265.5	N.P.	545.3	77.2	4.5	########	0	0.5	0.5	1	0.5	0.5	2	N.R.	N.R.	545.3	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
05	22	078	07W4	348.0	271.0	265.0	N.P.	511.4	77.0	8.0	########	0	3	1	4	1	0	5	182	197	511.4	329.4	314.4	100	33	3	73
11	23	078	07W4	353.0	271.0	265.0	N.P.	537.2	82.0	6.0	########	1	1	1	3	1	0	4	209	223	537.2	328.2	314.2	100	33	3	75
13	24	078	07W4	339.0	261.0	256.0	N.P.	550.7	78.0	5.0	########	0	0	0	0	0	0	0	231	248	550.7	319.7	302.7	100	60	2	33
10	27	078	07W4	349.0	275.0	267.0	215.0	555.7	74.0	8.0	32.0	0	1	0	1	1	0	2	227	240	555.7	328.71	313.71	60	47	3	33
07	29	078	07W4	345.6	270.4	265.0	211.0	549.2	75.2	5.4	54.0	0	1	0	1	0	0	1	226	237	549.2	325.2	312.2	100	36	2	52
07	33	078	07W4	343.5	271.0	266.4	N.P.	545.0	72.5	4.6	########	0	1	0	1	1	2	4	223	233	545.0	322	312	60	60	3	56
10	04	078	08W4	345.6	262.7	258.0	N.P.	558.4	82.9	4.7	########	0	4	0	4	N.P.	N.P.	4	229	251	558.4	329.4	307.4	100	60	N.P.	N.P.
11	06	078	08W4	346.6	265.2	258.5	N.P.	585.8	81.4	6.7	########	0	10	0	10	0	N.P.	18	266	271	585.8	330.8	314.8	80	100	3	N.P.
11	08	078	08W4	343.5	265.5	261.5	222.5	591.5	78.0	4.0	39.0	0	0	0	0	0	0	0	261	283	591.5	328.5	308.5	100	47	0	80
10	11	078	08W4	345.0	265.0	260.0	202.0	567.0	80.0	5.0	58.0	0	0	0	0	0	0	0	237	257	567.0	330	310	100	53	4	53
10	13	078	08W4	344.7	267.3	262.1	N.P.	530.0	77.4	5.2	########	0	1	1	2	1	1	4	202	218	530.0	328	312	100	60	3	N.P.
10	21	078	08W4	343.5	267.0	264.3	N.P.	570.3	76.5	2.7	########	0	2	0	2	0	1	3	246	259	570.3	325.3	311.3	100	44	0	52
10	26	078	08W4	349.0	276.6	269.6	235.6	563.6	72.4	7.0	34.0	0	3	2	4	1	0	5	233	247	563.6	330.6	316.6	30	60	3	47
03	30	078	08W4	344.4	270.4	263.4	N.P.	592.4	74.0	7.0	########	0	2	0	2	0	0	2	267	281	592.4	335.4	316.4	100	33	3	40
14	31	078	08W4	348.7	279.8	269.1	N.P.	623.3	68.9	10.7	########	0	0	0	0	0	0	0			623.3	623.3	623.3				
03	35	078	08W4	349.0	277.0	270.4	N.P.	569.0	72.0	6.6	########	0	3	1	3	1	0	4	230	252	569.0	339	317	100	30	3	N.P.
10	09	078	09W4	337.4	256.6	253.3	204.8	602.6	80.8	3.3	48.5	0	1	0	1	0	0	1	281	295	602.6	321.6	307.6	30	100	0	30
07	11	078	09W4	339.5	256.3	253.6	206.7	600.5	83.2	2.7	49.0	0	2	0	2	0	0	2	277	291	600.5	323.5	309.5	30	100	0	44
10	27	078	09W4	343.0	265.0	261.7	214.0	629.3	78.0	3.3	47.7	0	2	0	2	0	2	4	310	321	629.3	319.3	308.3	40	40	0	20
07	33	078	09W4	341.4	269.0	266.0	210.0	600.5	72.4	3.0	56.0	0	2	0	2	0	2	4	330	351	600.5	322.5	309.5	20	30	0	25
06	01	078	10W4	337.1	256.3	251.2	N.P.	619.0	80.8	5.1	########	0	6	0	6	2	1	9	297	308	619.0	322	311	20	100	3	N.P.
16	07	078	10W4	332.8	255.1	249.3	198.1	667.0	77.7	5.8	51.2	0	2	0	2	0	2	4	347	361	667.0	320	306	20	82	2	36
07	09	078	10W4	328.6	255.7	248.1	N.P.	641.0	72.9	7.6	########	0	2	0	2	0	1	3	324	337	641.0	317	304	30	100	N.P.	N.P.
10	11	078	10W4	335.6	258.2	252.1	197.8	622.1	77.4	6.1	54.3	0	1	0	1	1	1	3	301	314	622.1	321.1	308.1	20	100	3	33
10	18	078	10W4	329.2	256.0	250.5	196.3	666.3	73.2	5.5	54.2	0	0	0	0	0	0	0	330	342	666.3	328.3	304.3	20	100	1	40
04	31	078	10W4	328.6	258.5	253.3	200.0	674.4	70.1	5.2	53.3	0	0	0	0	0	4	4	363	376	674.4	313.4	300.4	10	100	0	40
03	35	078	10W4	332.5	260.0	255.0	203.3	650.7	72.5	5.0	51.7	0	0	0	0	0	4	4	336	347	650.7	315.7	303.7	20	100	1	48
07	35	078	10W4	329.8	259.7	251.2	201.3	661.4	70.1	8.5	49.7	0	0	0	0	0	0	0	349	360	661.4	313.4	301.4	20	80	1	70
06	07	078	11W4	341.0	255.0	247.0	206.0	699.0	90.0	8.0	41.0	0	0	0	0	0	0	0	372	385	699.0	327	314	0	80	0	48
05	10	078	11W4	335.0	249.0	243.0	211.0	705.0	86.0	6.0	32.0	0	0	0	0	2	0	2	391	404	705.0	314	301	0	100	0	32
11	11	078	11W4	335.0	247.0	243.0	196.0	688.0	88.0	4.0	47.0	0	0	0	0	0	0	0	373	385	688.0	315	305	10	100	3	33
06	20	078	11W4	344.0	246.0	239.0	200.0	691.0	98.0	7.0	39.0	0	0	0	0	0	0	0	378	391	691.0	313	300	0	90	0	32
12	30	078	11W4	335.0	254.0	250.0	210.0	688.0	81.0	4.0	40.0	0	0	0	0	0	0	0	371	389	688.0	317	299	20	100	3	47
10	33	078	11W4	329.0	248.0	242.0	203.0	700.0	81.0	6.0	39.0	0	0	0	0	0	0	0	390	405	700.0	310	295	0	55	3	60
10	05	079	03W4	340.0	263.0	256.0	170.0	552.0	77.0	7.0	86.0	0	0	0	0	2	12	14	263	254	552.0	300	298	80	55	2	100
07	06	079	03W4	329.0	258.0	252.0	155.0	556.0	71.0	6.0	97.0	0	0	0	0	0	6	6	262	261	556.0	304	295	60	55	2	100
00	07	079	03W4	334.0	267.0	260.0	152.0	555.5	67.0	7.0	108.0	0	0	0	0	1	17	18	241	252	555.5	314.5	303.5	80	55	3	100

11	08	079	03W4	326.0	254.0	248.0	155.0	552.0	72.0	6.0	88.0	0	0	0	0	1	3	4	262	261	552.0	310	291	100	53	3	100
09	09	079	03W4	325.0	244.0	238.0	146.0	544.0	81.0	6.0	92.0	0	0	0	0	0	0	0	222	261	544.0	311	283	100	47	2	80
15	10	079	03W4	320.0	251.0	245.0	148.0	539.2	69.0	6.0	97.0	0	0	0	0	0	0	0	222	252	539.2	317.2	287.2	100	40	1	90
10	11	079	03W4	322.0	253.0	248.0	164.0	534.0	69.0	5.0	84.0	0	0	0	0	0	0	0	215	244	534.0	319	290	80	53	2	73
16	11	079	03W4	326.0	255.0	248.0	170.0	529.0	71.0	7.0	78.0	0	0	0	0	0	0	0	208	237	529.0	321	292	100	53	4	87
02	17	079	03W4	331.0	250.0	244.0	157.0	553.1	81.0	6.0	87.0	0	0	0	0	0	0	0	227	266	553.1	326.1	287.1	60	47	1	93
10	01	079	04W4	334.0	266.0	259.0	167.0	559.5	68.0	7.0	92.0	0	1	0	1	1	15	17	210	257	559.5	321.5	302.5	100	60	3	100
06	03	079	04W4	321.6	247.5	239.6	140.8	553.4	74.1	7.0	98.8	0	0	0	0	0	0	0	247	268	553.6	306.6	285.6	100	47	3	76
10	05	079	04W4	300.8	238.7	232.3	143.6	520.3	62.1	6.4	88.7	0	0	0	0	0	1	1	210	243	520.3	302.3	277.3	100	64	2	15
11	07	079	04W4	315.0	242.0	235.0	143.0	513.7	73.0	7.0	92.0	0	0	0	0	0	0	0	211	234	513.7	302.7	270.7	80	53	3	27
06	19	079	04W4	328.0	254.0	247.0	149.0	478.8	74.0	7.0	98.0	0	0	0	0	1	1	2	166	187	478.8	312.8	291.8	100	47	3	27
07	20	079	04W4	332.0	261.0	255.0	160.0	506.6	71.0	6.0	95.0	0	0	0	0	0	2	3	167	210	506.6	319.6	296.6	100	60	1	60
10	22	079	04W4	332.0	264.0	256.0	141.0	493.5	68.0	8.0	115.0	0	0	0	0	1	5	6	172	196	495.5	321.5	297.5	100	60	2	87
05	23	079	04W4	338.6	268.5	259.1	148.4	539.8	70.1	9.4	110.7	0	0	0	0	2	10	12	213	235	539.8	326.8	304.8	100	52	3	100
12	25	079	04W4	332.0	264.0	257.0	172.0	474.0	68.0	7.0	85.0	0	0	0	0	1	9	10	166	174	474.0	320	300	100	55	3	100
10	26	079	04W4	340.0	270.0	263.0	159.0	478.0	70.0	7.0	104.0	0	2	1	3	1	14	18	182	172	478.0	326	306	100	53	4	100
10	27	079	04W4	331.0	265.0	258.0	153.0	475.3	66.0	7.0	105.0	0	0	0	0	0	9	9	184	174	475.5	321.3	301.3	100	60	4	100
11	28	079	04W4	339.0	271.0	263.0	155.0	475.8	68.0	8.0	108.0	0	0	0	0	0	15	15	169	169	475.8	327.8	306.8	100	60	3	100
07	29	079	04W4	332.0	264.6	256.6	155.8	476.4	67.4	8.0	100.8	0	0	0	0	1	7	8	184	175	476.4	322.4	301.4	100	60	3	78
10	30	079	04W4	313.6	250.2	242.0	136.2	482.0	63.4	8.2	105.8	0	0	0	0	0	0	0	176	195	482.0	307	287	100	60	2	30
06	31	079	04W4	317.0	254.0	248.0	137.0	473.3	63.0	6.0	111.0	0	0	0	0	1	1	2	162	183	473.3	311.3	290.3	100	60	3	73
10	33	079	04W4	335.3	266.4	258.5	160.0	474.3	68.9	7.0	98.5	0	0	0	0	0	12	12	183	173	474.3	321.3	301.3	100	60	1	100
07	35	079	04W4	325.5	261.5	254.2	157.0	479.7	64.0	7.3	97.2	0	0	0	0	1	7	8	160	184	479.7	319.7	295.7	100	60	2	100
07	01	079	05W4	328.0	255.0	248.0	168.0	550.7	73.0	7.0	80.0	0	0	0	0	0	7	7	216	259	550.7	314.7	291.7	80	40	2	87
13	01	079	05W4	tight																		0	0				
10	02	079	05W4	340.0	271.0	264.0	191.0	540.4	69.0	7.0	73.0	0	1	0	1	1	15	17	209	232	540.4	331.4	308.4	100	53	3	73
05	03	079	05W4	332.0	262.0	256.0	181.0	537.0	70.0	6.0	75.0	0	0	0	0	0	2	2	213	238	537.0	324	299	80	54	2	48
13	04	079	05W4	338.0	266.0	259.0	184.0	501.6	72.0	7.0	75.0	0	0	0	0	1	7	8	174	198	501.6	327.6	303.6	60	53	2	87
04	05	079	05W4	336.0	266.0	260.0	176.0	533.0	70.0	6.0	84.0	0	0	0	0	1	8	9	208	231	533.0	325	303	50	47	1	67
06	06	079	05W4	341.0	264.0	258.0	166.0	538.8	77.0	6.0	92.0	0	0	0	0	1	7	8	214	237	538.8	324.8	301.8	60	60	2	67
07	07	079	05W4	337.0	265.6	260.0	186.0	504.5	72.0	5.0	74.0	0	0	0	0	1	8	9	179	201	504.5	325.5	303.5	60	53	3	53
05	08	079	05W4	336.0	267.0	262.0	186.0	498.9	71.0	5.0	76.0	0	0	0	0	0	8	8	172	195	498.9	326.9	303.9	80	60	1	60
08	09	079	05W4	339.0	268.0	261.0	188.0	513.2	71.0	7.0	73.0	0	0	0	0	1	11	12	188	207	513.2	328.2	306.2	80	55	2	100
07	12	079	05W4	331.0	259.0	252.0	167.0	532.0	72.0	7.0	85.0	0	0	0	0	0	6	6	213	236	532.0	319	296	80	60	3	73
03	15	079	05W4	327.0	262.0	256.0	180.0	493.3	65.0	6.0	76.0	0	0	0	0	1	7	8	172	194	493.3	321.3	299.3	80	53	2	100
05	16	079	05W4	335.5	268.0	261.0	176.5	472.5	67.5	7.0	84.5	0	0	0	0	0	9	9	166	168	472.5	326.5	304.5	80	53	4	100
05	17	079	05W4	337.0	267.0	261.0	183.0	474.8	70.0	6.0	78.0	0	1	0	1	1	9	11	160	170	474.8	326.8	304.8	60	47	3	47
06	18	079	05W4	332.0	267.0	261.0	185.0	474.0	65.0	6.0	76.0	0	1	0	1	1	8	10	167	160	474.0	327	305	60	53	2	60
12	19	079	05W4	340.0	265.0	260.0	173.0	478.3	75.0	5.0	87.0	0	0	0	0	0	7	7	168	176	478.3	323.3	302.3	100	53	0	47
12	20	079	05W4	337.0	262.0	256.0	163.0	481.6	75.0	6.0	93.0	0	0	0	0	0	5	5	160	183	481.6	321.6	298.6	100	55	1	80
06	23	079	05W4	332.0	260.0	253.0	166.0	485.3	72.0	7.0	87.0	0	0	0	0	0	3	3	169	189	485.3	316.3	294.3	60	60	2	67
15	25	079	05W4	tight																		0	0				
06	26	079	05W4	tight																		0	0				
06	28	079	05W4	317.0	254.0	248.0	163.0	490.0	63.0	6.0	85.0	0	0	0	0	0	1	1	176	198	490.0	314	292	60	47	1	53
05	29	079	05W4	345.0	268.0	262.0	190.0	483.2	77.0	6.0	72.0	0	0	0	0	1	7	8	166	177	483.2	327.2	306.2	60	60	1	60
13	29	079	06W4	326.0	253.0	246.0	172.0	492.0	73.0	7.0	74.0	0	0	0	0	1	6	7	177	200	492.0	315	292	60	60	1	48
05	30	079	05W4	344.0	266.0	260.0	192.0	477.3	78.0	6.0	68.0	0	0	0	0	1	8	9	160	172	477.3	327.3	305.3	100	53	2	67
10	31	079	05W4	340.0	264.0	258.0	183.0	460.8	76.3	6.0	73.0	0	0	0	0	1	7	8	128	160	460.8	322.8	300.8	100	53	1	60
13	32	079	05W4	341.0	269.0	262.0	N.P.	478.6	72.0	7.0	#######	0	0	0	0	1	1	2	181	173	478.6	327.6	305.6	100	53	2	60
07	33	079	05W4	335.0	269.0	263.0	180.0	486.0	69.0	6.0	83.0	0	0	0	0	1	8	9	162	180	486.0	324	306	100	53	2	27
11	01	079	06W4	D.W.	264.2	258.7	N.P.	525.2	#######	3.5	########	N.P.	N.P.	0	0	0	4	4	D.W.	D.W.	525.2	D.W.	D.W.	D.W.	D.W.	1	60
13	02	079	06W4	339.0	263.0	258.0	N.P.	491.8	78.0	3.0	########	0	0	0	0	1	5	6	169	190	491.8	322.8	301.8	50	47	2	60
12	03	079	06W4	346.0	274.0	269.0	196.0	507.2	72.0	5.0	71.0	0	0	0	0	1	7	8	176	197	507.2	331.2	310.2	60	67	1	53
08	04	079	06W4	340.0	266.5	261.0	192.0	512.5	73.5	5.5	66.0	0	0	0	0	1	6	7	187	207	512.5	325.5	303.5	80	55	3	67
11	06	079	06W4	340.0	268.0	262.7	200.0	554.7	72.0	5.3	62.7	0	0	0	0	1	3	4	227	246	554.7	327.7	308.7	100	52	2	40
11	08	079	06W4	342.6	271.6	267.0	193.6	510.6	71.0	4.6	73.4	0	0	0	0	0	4	4	188	198	510.6	330.6	312.6	100	47	3	40
07	10	079	06W4	341.0	268.0	262.5	200.0	478.0	73.0	5.5	62.5	0	0	0	0	1	9	10	181	173	478.0	327	305	100	60	1	67

10	11	079	06W4	342.0	271.5	263.0	190.0	494.5	70.5	8.5	73.0	0	0	0	0	0	1	1	170	191	494.5	324.5	303.5	100	60	0	13
06	12	079	06W4	341.0	266.3	261.0	180.0	479.3	74.7	5.5	61.0	0	0	0	0	0	8	8	163	176	479.3	326.3	303.3	70	53	1	73
08	13	079	06W4	336.2	264.6	258.2	174.0	476.2	72.7	5.8	64.3	0	0	0	0	0	5	5	162	176	476.2	323.2	300.2	100	53	2	40
08	14	079	06W4	341.3	264.3	256.3	188.3	471.3	77.0	8.0	68.0	0	0	0	0	1	1	2	166	148	471.3	325.3	303.3	100	53	2	40
07	15	079	06W4	342.7	268.0	262.7	184.0	468.7	74.7	5.3	78.7	0	0	0	0	1	7	8	142	163	468.7	326.7	303.7	50	47	3	60
10	16	079	06W4	340.0	267.0	261.0	178.0	491.4	73.0	6.0	85.0	0	0	0	0	1	8	9	166	187	491.4	326.4	304.4	60	47	1	60
11	20	079	06W4	343.0	271.6	265.5	194.0	536.8	71.4	6.1	71.5	0	0	0	0	1	8	9	205	232	536.8	351.8	304.8	60	53	73	
10	21	079	06W4	344.0	272.0	266.0	N.P.	482.7	72.0	6.0	#######	0	0	0	0	1	8	9	163	175	482.7	329.7	307.7	40	53	1	40
11	22	079	06W4	342.6	267.6	257.9	181.4	479.1	75.0	9.7	76.5	0	0	0	0	1	10	11	164	174	479.1	325.1	303.1	100	53	2	60
09	23	079	06W4	338.0	266.0	259.0	N.P.	467.0	72.0	7.0	#######	0	0	0	0	1	2	3	142	164	467.0	325	300	100	53	2	40
06	24	079	06W4	344.0	270.6	264.0	N.P.	473.6	73.4	6.6	#######	0	0	0	0	1	0	1	148	165	473.6	328.6	306.6	50	47	2	7
10	25	079	06W4	346.0	272.0	266.0	N.P.	473.1	74.0	6.0	#######	0	0	0	0	1	9	10	144	165	473.1	329.1	308.1	100	53	2	53
09	26	079	06W4	344.5	271.5	265.5	N.P.	457.5	73.0	6.0	#######	0	0	0	0	1	9	10	120	151	457.5	329.5	306.5	100	53	2	47
11	28	079	06W4	341.5	273.0	266.0	187.0	517.0	68.5	7.0	79.0	0	0	0	1	1	8	9	187	207	517.0	330	310	100	60	1	53
07	32	079	06W4	340.0	270.5	264.5	195.5	550.5	69.5	6.0	69.0	0	1	0	1	1	10	12	222	244	550.5	328.5	306.5	100	47	3	73
06	34	079	06W4	346.6	273.0	261.0	190.0	506.3	73.6	12.0	71.0	0	1	1	2	1	8	10	175	197	506.0	331	309	100	53	3	60
13	35	079	06W4	344.3	272.3	266.3	N.P.	502.3	72.0	6.0	#######	0	1	0	0	1	5	8	172	190	502.3	330.3	308.3	100	53	2	33
08	36	079	06W4	347.2	272.7	266.7	N.P.	456.2	74.5	6.0	#######	0	0	0	0	0	8	8	126	148	456.2	330.2	308.2	100	47	2	47
11	02	079	07W4	346.4	275.4	N.P.	N.P.	550.4	71.0	#######	#######	0	0	0	2	1	10	11	216	236	550.4	335.4	314.4	100	53 N.P.	N.P.	
11	03	079	07W4	351.0	274.6	269.0	207.0	557.5	77.0	5.0	62.0	0	3	0	1	N.P.	N.P.	3	223	245	557.5	334.5	312.5	80	53	2	67
10	05	079	07W4	350.0	275.5	270.0	218.5	566.5	74.5	5.5	51.5	0	1	0	1	1	2	4	230	251	566.5	336.5	315.5	60	47	2	53
11	08	079	07W4	353.0	279.2	274.2	239.0	572.2	73.8	5.0	35.2	0	0	0	0	0	2	2	232	255	572.2	340.2	319.2	60	47	2	27
10	11	079	07W4	345.0	274.0	269.0	218.0	553.8	71.0	5.0	51.0	0	0	0	0	1	5	6	220	243	553.8	333.8	310.8	10	47	2	33
11	13	079	07W4	341.4	271.0	265.6	216.0	536.4	70.4	5.6	49.4	0	0	0	0	0	3	3	205	228	536.4	331.4	308.4	100	47	2	47
06	15	079	07W4	346.0	272.0	266.0	213.5	571.0	74.0	6.0	52.5	0	0	0	0	0	3	3	240	260	571.0	331	311	100	47	2	47
07	21	079	07W4	350.5	276.0	271.5	215.3	584.5	74.5	4.7	56.0	0	0	0	0	0	2	2	247	269	584.5	337.5	315.5	100	47	3	60
10	25	079	07W4	349.4	277.4	272.0	215.4	569.4	72.0	5.4	56.6	0	0	0	0	1	1	2	233	255	569.4	336.4	314.4	60	47	2	73
06	26	079	07W4	345.0	273.4	268.0	211.3	569.2	71.6	5.4	56.7	0	1	1	2	0	0	2	237	259	569.2	332.2	310.2	100	47	2	73
10	32	079	07W4	349.3	276.0	271.3	217.0	592.0	73.3	4.7	54.3	0	0	0	0	0	3	3	256	277	592.0	336	315	100	47	3	60
01	33	079	07W4	349.6	277.7	272.2	216.1	585.0	71.9	5.5	56.1	0	0	0	0	0	4	4	248	271	585.0	337	316	60	47	2	36
11	35	079	07W4	348.6	279.0	273.0	218.0	593.6	67.6	6.0	55.0	0	1	0	1	1	3	4	256	278	593.6	338.6	315.6	100	0	2	73
10	08	079	08W4	349.0	274.0	267.5	222.0	615.0	75.0	6.5	45.5	0	0	2	2	0	0	2	278	302	615.0	337	313	100	0	3	67
10	11	079	08W4	349.0	277.0	272.0	215.0	577.4	72.0	5.0	57.0	0	0	0	0	0	0	0	238	262	577.4	339.4	315.4	100	0	3	40
10	12	079	08W4	349.0	274.8	268.8	226.8	573.1	74.2	6.0	42.0	0	2	1	2	1	0	4	233	255	573.1	340.1	318.1	100	33	3	33
12	14	079	08W4	356.4	279.4	272.4	222.4	593.4	77.0	7.0	50.0	0	1	1	2	1	1	4	262	280	593.4	342.4	315.4	100	33	2	60
10	26	079	08W4	355.6	276.4	271.9	225.9	618.4	79.2	4.5	46.0	0	0	0	0	0	0	0	270	303	618.4	340.4	315.4	100	27	2	47
10	31	079	08W4	355.4	277.7	272.8	226.5	673.9	77.7	4.9	46.3	0	1	1	2	0	0	2	333	357	673.9	340.9	316.9	100	40	2	63
06	03	079	09W4	339.2	268.2	263.3	214.9	658.4	71.0	4.9	48.4	0	1	1	2	0	0	2	336	357	658.4	322.4	301.4	60	40	3	32
06	11	079	09W4	341.7	274.0	268.5	224.0	640.4	67.7	5.5	44.5	0	1	0	1	1	1	3	318	329	640.4	321.4	311.4	60	38	3	68
10	16	079	09W4	337.7	267.9	263.3	212.8	660.3	69.8	4.6	50.5	0	1	0	1	0	0	1	341	370	680.3	319.3	310.3	60	40	3	70
10	36	079	09W4	358.5	285.0	274.5	228.5	676.5	73.5	10.5	46.0	0	0	0	0	0	0	0	337	337	676.5	339.5	319.5	60	20	3	20
07	21	079	10W4	340.8	277.4	267.6	215.5	680.3	63.4	9.8	52.1	0	0	0	0	0	0	0	344	369	680.3	336.3	311.3	20	40	0	24
07	26	079	10W4	332.5	271.6	260.9	210.6	683.7	60.9	10.7	50.3	0	0	0	0	0	0	0	372	378	683.7	311.7	303.7	20	0	0	20
10	29	079	10W4	320.5	271.0	261.5	204.5	668.5	58.5	9.5	57.0	0	0	0	0	0	6	6	366	370	668.5	313.5	298.5	20	0	0	50
10	06	079	11W4	336.0	267.0	263.0	N.P.	683.0	69.0	4.0	#######	0	0	0	0	0	0	0	363	377	683.0	321	306	60	40	0	40
10	11	079	11W4	335.0	248.0	243.0	N.P.	688.0	87.0	5.0	#######	0	0	0	0	0	0	0	382	395	688.0	306	295	40	40	3	30
11	29	079	11W4	342.0	259.0	257.0	207.0	691.0	83.0	2.0	50.0	0	0	0	0	0	0	0	378	389	691.0	315	302	20	30	1	10
11	29	079	11W4	346.0	269.0	263.0	210.0	697.0	77.0	6.0	53.0	0	0	0	0	2	3	5	372	386	697.0	325	311	60	30	3	67
13	30	079	11W4	336.0	259.0	254.0	208.0	693.0	77.0	5.0	46.0	0	0	0	0	0	0	0	370	390	693.0	323	303	10	40	3	36
11	31	079	11W4	339.0	262.0	256.0	204.0	692.0	77.0	6.0	52.0	0	0	0	0	0	0	3	360	386	692.0	324	306	10	20	3	87
13	36	079	11W4	tight																							

Appendix C

Cross-Sections

Figure 42	C.1 - Cross-Section Location Map.
Figure 43	C.2 - Section A - A' : Dip Section Of Study Area.
Figure 44	C.3 - Section B - B' : Strike Section In Undisturbed Zone.
Figure 45	C.4 - Section C - C' : Strike Section In Collapse Zone.
Figure 46	C.5 - Section D - D' : Structure Of Clearwater B' Sand in Leismer Field.
Figure 47	C.6 - Section D - D' : Stratigraphic Section Through Leismer Field.
Figure 48	C.7 - Section E - E' : Structure Of McMurray Fm. Through Chard Field.
Figure 49	C.8 - Section E - E' : Stratigraphic Section Through Chard Field.
Figure 50	C.9 - Section F - F' : Structure Of McMurray Formation Through Graham Field.
Figure 51	C.10- Section F - F' : Stratigraphic Section Through Graham Field.

Appendix D

Thesis Maps

Structure Maps

Figure 52 D.1 - Clearwater Fm. Structure Map
Figure 53 D.2 - Clearwater 'A' Structure Map
Figure 54 D.3 - Clearwater 'B' Structure Map
Figure 55 D.4 - Wabiskaw Member Structure Map
Figure 56 D.5 - McMurray Fm. Structure Map
Figure 57 D.6 - SubCretaceous Unconformity Structure

Isopach and Facies Maps

Figure 58 D.7 - Clearwater Fm. Isopach Map
Figure 59 D.8 - Clearwater'A';Top 5 m Ss./Sh. Ratio Map
Figure 60 D.9 - Clearwater'B';Top 15 m Ss./Sh. Ratio
Figure 61 D.10 - Wabiskaw Member Isopach Map
Figure 62 D.11 - McMurray Fm. Isopach Map
Figure 63 D.12 - McMurray Fm.; Top 15 m Ss./Sh. Ratio

Net Pay Maps

Figure 64 D.13 - Clearwater 'A' Net Pay Map
Figure 65 D.14 - Clearwater 'B' Net Pay Map
Figure 66 D.15 - Clearwater 'C' Net Pay Map
Figure 67 D.16 - Clearwater Fm. Net Pay Map
Figure 68 D.17 - Wabiskaw Member Net Pay Map
Figure 69 D.18 - McMurray Fm. Net Pay Map